

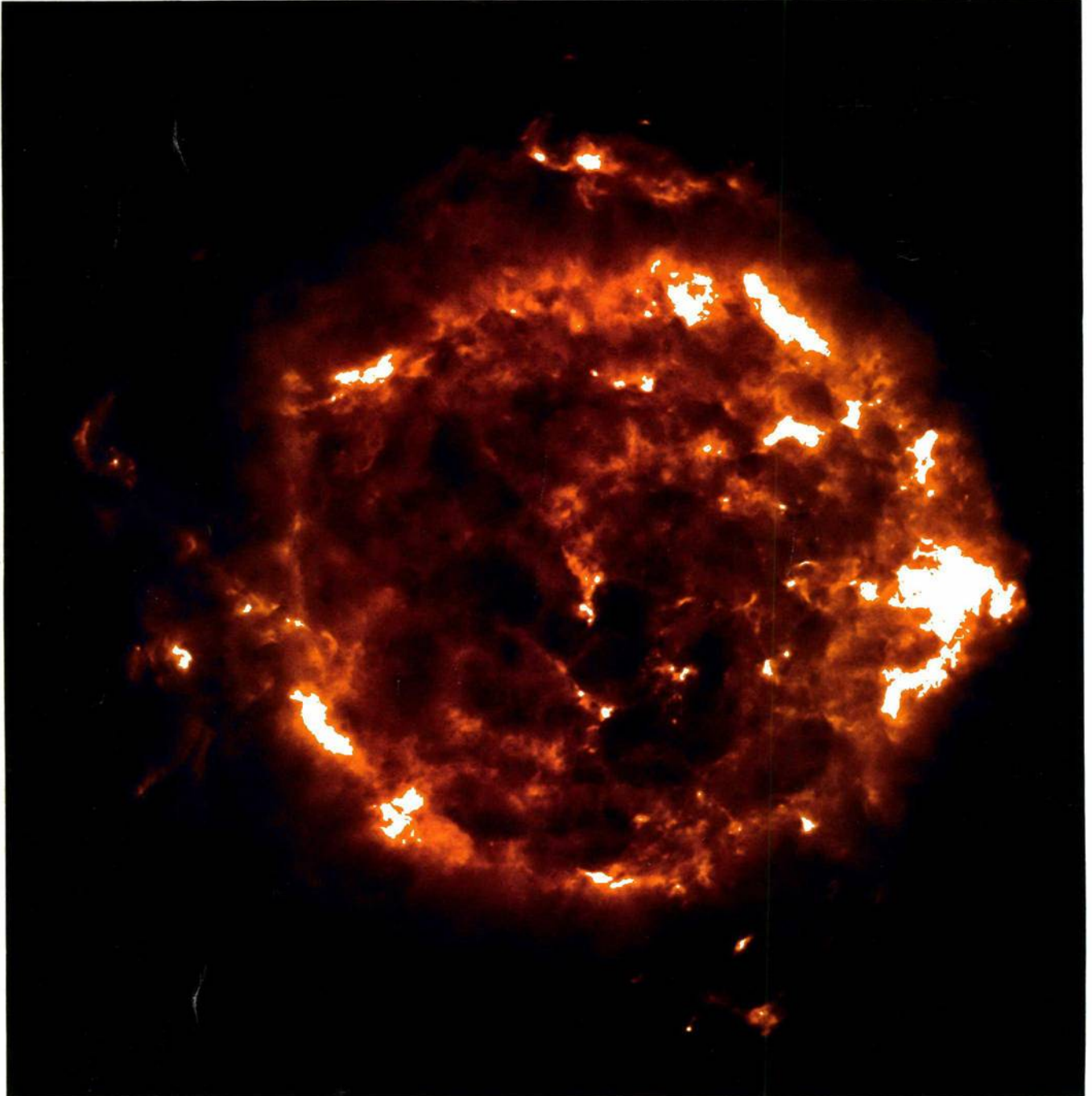
APRIL SOUTHERN SKY CHART INSIDE

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Aftermath of a Supernova



Meade® Wide-Field f/6.3 SCT's:



For the First Time Ever — Wide-Field Schmidt- Cassegrain Telescopes that Yield a 60% Reduction in Photo Exposure Times!

New Meade 8" and 10" LX6 Wide-Field Schmidt-Cassegrains combine the wide fields of view, fast photo exposure times, and high-contrast imaging long sought by the serious amateur. Consider this listing of *standard* LX6 features:

1 Fast f/6.3 Schmidt-Cassegrain Optics — Optics that yield photographic and visual performance impossible to achieve with the f/10 optics that are standard on all other SC telescopes. Eyepiece for eyepiece, obtain:

□ A field of view that is **59%** wider than with f/10 Schmidt-Cassegrains. Use the Meade Super Wide Angle 40mm eyepiece on the 8" LX6 to

Meade 8"
Model 2080/LX6



future date, and is available at only modest additional cost.

accessories including the Meade **CAT Computer Aided Telescope** system (see our other ad in this issue), with its library of more than 8000 astronomical objects; **Digital Readouts**, readable on the LX6 hand controller (see above); **#1200A Electric Focuser**, for ultraprecise microfocusing; **12mm Illuminated Reticle Eyepiece**, for guiding during astrophotography; and the **Declination Motor**, for 2X/8X dual-axis operation.

In addition, the LX6 power panel includes an **Ammeter**, which continuously displays electric current usage, to gauge battery life during power cell operation; a **North-South Switch**, permitting your LX6 to be used anywhere in the world — simply flip the N-S switch to reverse drive direction for use in the Southern hemisphere; and **12-volts DC Power Inlet**. Each LX6 includes power cords for 3 types of field operation: Directly from auto cigarette lighter plugs; directly from 115v. AC home outlets; and from the Battery Pack, included, using AA-size batteries supplied by the user.

7 Plus all of the features you expect on a top-of-the-line Meade Schmidt-Cassegrain

The LX6 Revolution Is Here.

obtain a true field over 2 degrees in diameter!

□ Images both visually and photographically that are **2 1/2 times** brighter than with an f/10 system.

□ A **60%** reduction in astrophoto exposure times: 30 minute exposures become 12 minute exposures. Used with modern fast films, a **5-minute** color exposure of the Orion Nebula (M42) taken with the 10" Model 2120/LX6 yields virtually all of the nebular detail that is theoretically possible to obtain with a 10" telescope! With the optional Meade **Telecompressor Lens**, for an effective focal ratio of f/3.15, this exposure time is reduced still further to about **3 minutes** — an unheard of exposure time for a photo-visual telescope of 10" aperture, an exposure time that means anyone with an absolute minimum of experience can take magnificent deep-space astrophotos!

2 Ultra High Contrast Baffling — In addition to their superlative wide-field deep-space performance, Meade 8" and 10" LX6 models, because of their computer-optimized internal light baffles, yield uncompromised, high-contrast lunar and planetary images. Add the Meade 3-element **#140 2X Telenegative Barlow Lens** to obtain high-power lunar and planetary images at f/12.6.

3 Built-In Digital Readout Capability — One of the most important optional features ever made available on a Schmidt-Cassegrain: now you can find faint objects in seconds, not minutes. The LX6 Digital Readouts, located on the hand controller display, permit continuous monitoring of: (a) telescope position in RA and Dec; (b) Local Time; (c) Sidereal Time; (d) a Digital Timer for photo exposures; and (e) Frequency readout of the pulse motor's input current — a feature that enables extremely precise digital settings of the telescope's drive rate, readable to within ± 0.1 Hz. The observer simply depresses the "Mode" button on the hand controller to read out the listed data sequentially.

The Digital Readout package can be internally added easily and rapidly to the hand controller of your LX6, either at the time of purchase or at any

4 New Multi-Function Electronic Command Center — The ECC hand controller, included as standard equipment, puts virtually every telescope function at your fingertips:

□ **2X Drive Correction Speed** for precise electronic corrections during astrophotography.

□ **8X Scanning Speed** for rapid electronic centering of the image in the field, or for roving about a specific sky region at 8 times the sidereal speed. Add the optional Declination motor for full dual-axis capability at 2X or 8X speeds.

□ **Optional Digital Readouts**, described above.

□ **Plus 6 other functions** that make Meade LX6's the only state-of-the-art Schmidt-Cassegrains available.

5 Quartz Microprocessor-Controlled Electronic and Drive Systems — The heart of every LX6 electronic system is a dedicated microprocessor that continuously controls, with quartz precision, all important electronic operations of the telescope, from the drive-rate frequency input to the main RA pulse motor, to the Electronic Command Center's multi-function digital readouts.

Augmented by the microprocessor, the RA pulse motor and LX worm gear system achieve true sidereal-rate tracking within $\pm 0.005\%$ of the sidereal frequency, and with greater reliability than ever before. Switch to the "Manual" mode for variable Solar, Lunar, or Planetary tracking rates.

6 Advanced-Design Power Panel — Virtually every modern electronic accessory you might wish to add to your LX6 can be plugged-in directly to the telescope's power panel —

— *Standard* features that include a **Super Plössl 26mm eyepiece** for exquisite definition and resolution across the entire visual field; 1/10-wave flat, multi-coated **2" Diagonal Mirror** with eyepiece holders for both 1 1/4" and 2" eyepieces; **9 x 60mm Polar Illuminated Viewfinder**, the largest finder available on a commercial SCT; **Multi-Coated Optics Group**, with multi coatings on all lens and mirror surfaces for maximum light transmission and image brightness; **Equatorial Wedge**, with magnetic compass, latitude scale, bubble level, and micrometric azimuth control; and **Variable-Height Field Tripod**, the most stable in the industry.

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ON THE COVER: Three hundred years after a cataclysmic stellar explosion the Cassiopeia A supernova remnant continues to evolve.



A HOLE IN THE SKY or dark matter between the stars? This question troubled astronomer Edward Emerson Barnard for nearly forty years. The dark nebula is Barnard 86; the star cluster is NGC 6520.

ASTRONOMY®

February 1989

Vol. 17, No. 2

20 **Searching for the 'Real' Triton**

Scientists await Voyager 2's view of Neptune's moon. By Richard Berry.

30 **Barnard's 'Dark' Dilemma**

Did Barnard understand the dark nebulae he discovered? By Gerrit L. Verschuur.

40 **Supernova Aftermath**

The death of a star produced an expanding shell of gas. By Laurence A. Marschall.

46 **An Uphill Battle for Comet Research**

Astronomers take on winter to study comets. By Lys Ann Shore.

56 **ASTRONOMY Sky Almanac**

66 **Equipped for Safe Solar Viewing**

Safety is the key when choosing equipment for solar observing. By Richard Hill.

71 **Eclipse Prospects for the 1990s**

Get ready for the last eight total eclipses of the century. By Jay Anderson.

78 **A Picture-Perfect Lunar Eclipse**

Capture this month's unusual lunar eclipse on film. By David J. Eicher.

80 **Legendary Faint Galaxies**

These deep-sky objects will test your observing skills. By Steve Lucas.

84 **Sharpen Images with a Cardboard Mask**

Use a stop-down mask on your large-aperture reflector. By M. Leon Knott.

88 **Working against the Grain of Fast Films**

Reduce the grain in your photos with this printing technique. By Larry Myers.

Departments

6 **Behind the Scenes**

6 **Letters**

8 **Viewpoint**

Cosmological Imperative

10 **AstroNews**

Pulsar Erodes Companion

16 **Space News**

U.S./Soviet Cooperation

18 **Amateur News**

Big Scope View of Mars

92 **Reader Reports**

98 **Forum**

100 **Astronomy Books**

104 **Astronomy Products**

106 **Meetings and Events**

108 **Readings and Resources**

108 **Credits**

110 **Advertiser Index**

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AN ITCH TO KNOW

The itch to know drives astronomers to explore the universe. Call it curiosity, the urge to explore, or a search for novelty — the result is the same. Human beings aren't happy unless they're learning about the world around them.

But we pay a price for the knowledge we acquire: Much of what we hold true in the world of science is only temporary. Within a few years, a few decades, or a few hundred years the scientific view of the universe changes. Unfortunately change doesn't come easily even to the astronomers who make discoveries that bring about change.

Two feature stories this month deal with change. "Barnard's 'Dark' Dilemma" tells how eighty years ago E. E. Barnard wrestled with his discovery of dark matter between the stars. "Searching for the 'Real' Triton" examines the predictable discoveries yet to be made when *Voyager 2* flies past Neptune's satellite Triton on August 25.

In resisting his own discovery, Barnard was only human. Dust between the stars made him uneasy. Perhaps the mental image of the starry sky he had formed in his youth simply didn't have dust in it, so he had difficulty accepting the dust even when his photographs told him otherwise.

Planetary astronomers frankly admit how little they know about Triton. However, after years of observing and thinking about Triton, they have ideas that *Voyager's* findings will put to the test. Will it be easy for them? Certainly not, but it's part of doing science to test ideas against observation.

I learned basic astronomy before the Big Bang theory gained strong favor among astronomers. Astronomers still took the steady state theory seriously back in the 1950s, even though this theory had grave difficulties.

The steady state was a wonderfully satisfying picture of the universe, because it implied that the universe was literally forever, with no beginning and no end. Yet the theory didn't explain discoveries such as quasars and the cosmic background radiation, so it landed on the scrap heap with thousands of other discarded ideas.

The scientific view of the world grows and changes, always responding to fresh observation and experiment. To enjoy the adventure of discovering our universe requires seeing clearly — and keeping our minds open.

Sincerely,



Richard Berry
Editor-in-Chief

ASTRONOMY

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'Mars Mania' a Great Idea

Thank you for the wonderful idea about "Mars Mania" (Behind the Scenes, May 1988). The Denver Astronomical Society held a successful open house at historic Chamberlin Observatory and gave nearly two thousand people a good look at Mars. Many of the visitors donated a dollar to view Mars through the 20-inch Alvan Clark refractor.

These donations went into our fund to restore the observatory, which has been used primarily for public education in the last fifty years, to its turn-of-the-century appearance. If anyone is interested in making a tax-deductible donation, send it to: Denver Astronomical Society, P.O. Box 10814, Denver, CO 80210. — *Dave Trott, Aurora, Colorado*

Overcoming the Big Scope Burden

Tom Clark does a fine job of communicating how rewarding deep-sky observing is with a big scope ("The Lure of a Big Scope," October 1988). Once you're accustomed to viewing galaxies and nebulae with a 17.5-inch telescope, it's hard to go back to smaller apertures.

What Mr. Clark wrote about the difficulties of handling and transporting a big scope is true for the old-style Dobsonians. However, a solution to these difficulties is converting to, making, or purchasing an open-tube design that uses aluminum struts. This design is lighter because most of the weight of the old-style Dobsonians is in the cardboard tube.

None of the separate pieces of my telescope weighs more than fifty pounds, so I can carry my telescope alone and transport it in the back of my hatchback car. — *Jim Shields, San Francisco, California*

— Telescope Making, produced by the staff of *ASTRONOMY*, has published articles about open-tube Dobsonians. More articles on this design will be featured in the upcoming issue, #35.

Astronomy in Our Textbooks

We were glad to see photos from our elementary and junior high school science textbooks in "Astronomy in Our Schools" by Stephen Cole (September 1988). Working with a mainstream publisher, as we did, has proved worthwhile, because 1 million copies of *Physical Science* and *Earth Science* are now in use.

Most copies of these texts are purchased by schools and used year after year, so millions of students have been exposed to the expanded, updated, and factually correct astronomy we have been able to provide. We hope that the result

"Your Eyepiece Has Given Me the Most Pleasant Case of Insomnia Imaginable"

Tom Lorenzin, author of "1000+ Guide to Deep Sky Observing"

Discover Type 2 Nagler Eyepieces

These new designs extend the Nagler concept to impressive new performance levels, while retaining the basic advances of the original Naglers:

- 82° apparent field
- full field correction
- fast aperture correction, to f/4

New Features Include:

First: longer focal lengths produce wider true fields of view.

Second: full exit pupil correction permits comfortable night and day use.

Third: fold-down rubber eyeguards are included for maximum comfort and dark adaptation.

Fourth: they are relatively lightweight, moderately sized, and include knurled rubber grip rings for easier handling.

Design Goals

The basic Nagler series has already achieved image correction 10 times better than previous wide angle eyepieces (study in "Telescope Making" titled "The Nagler 13, a Remarkable Telescope Eyepiece"). We felt that extending the apparent field or image correction levels beyond that of the original Nagler series would not yield significant practical gains, but that extending the focal lengths would offer enormous potential for spectacular low power, wide-angle viewing.

In order to produce longer focal length Naglers, two practical limits had to be overcome:

- 1) Substantial physical size, weight, and cost increases would be impractical.
- 2) Scaling up exit-pupil aberrations would be unacceptable in our judgement. Although the 13mm Nagler eye-



piece provides extremely sharp images, exit-pupil aberrations require a large (nighttime) eye pupil opening to encompass the full field. For this reason, daytime viewing with the 13mm Nagler is not recommended. Eye positioning is just too sensitive with the 7 element design to consider focal lengths longer than 13mm. The 9mm and shorter Naglers don't show this sensitivity.

Nagler Type 2: The design breakthrough!

The patented (#4,747,675) 8-element design achieves pupil aberration correction far beyond any eyepieces produced with such large apparent fields. Each model is a unique design, with eye relief similar to the 9mm Nagler, yet surprisingly compact, lightweight and affordable. Extensive computer-aided design efforts and the use of new glass types retain the superb full-field and fast aperture sharpness of the 7-element Naglers. Our pioneering lens edge-blackening and multi-coating techniques also maximize contrast.

A special rubber eye-

guard aids viewing comfort, eliminating stray light and enhancing dark adaptation. This helps in detecting faint, delicate nebulosity and comets. The eyeguard is a delight on cold nights too.

20mm Nagler Type 2

Has the largest true field in the series. Yet this eyepiece, (strictly for 2 inch focusers) is comparable in size and weight to a 13mm Nagler. There's nothing like this 20mm for viewing large open clusters, galaxies and nebulae. It gives a 4.5mm exit-pupil with f/4.5 telescopes. Daytime viewing is also simply stunning!

16mm Nagler Type 2

Offers far more true field than the 13mm Nagler, yet is smaller and lighter. Great day or night performance with any telescope.

"There is nothing like this eyepiece (20mm Nagler) for viewing large deep-sky open clusters, galaxies, and nebulae. Under ideal conditions at Yosemite National Park, I was treated to incredible views of M8, M13, M17, M22, M31, and M33. I had believed that my C-8 would never perform visually with photographic quality, but my observations with the Nagler rivaled the detail in good astrophotography and even surpassed it at times. I was amazed and deeply satisfied. Thank you for the ultimate eyepiece."

Ben Cohen, CA

12mm Nagler Type 2

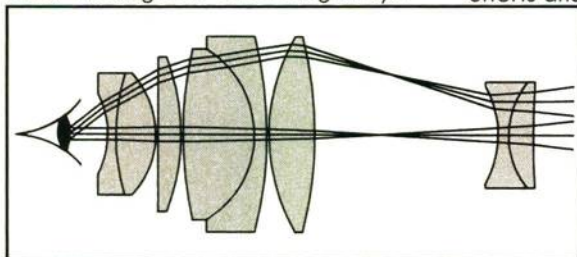
As superb as the 16mm, but with higher magnification. An excellent alternate to the 13mm Nagler, which has a longer eye relief for people who MUST wear eyeglasses to correct severe astigmatism.

The 16mm and 12mm Type 2 Naglers work beautifully with Tele Vue Barlows. These 1 1/4" barrel eyepieces can also be used with 2" focusers.

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is an improved, long-term appreciation of astronomy. — Jay M. and Naomi Pasachoff, Paris, France

Cloudy Night Galaxies

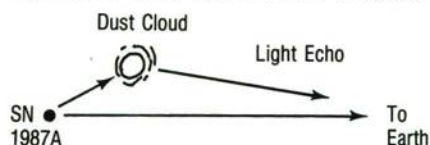
Thank you for publishing the galaxy collision computer program in "Galactic Collisions on Your Computer" (December 1988). I have entered the program in my IBM-AT compatible and have run it a number of times.

I live in the Pacific Northwest, and because the area is plagued by cloudy skies, I especially appreciate being able to do some astronomy on my computer when the night is stormy. — John H. Lincoln, Seattle, Washington

Geometry of a Light Echo

Your AstroNews article on the rings of light encircling supernova 1987A (November 1988) left me confused. How can rings of light, one 470 light-years from the supernova and the other at least 1,200 light-years away, appear so far from the supernova only a little more than a year after the star exploded? — Marc N. Miller, Brooklyn, New York

— The answer is that while the light echoes were traveling away from the supernova, they were traveling in the general direction of Earth. Light from the supernova itself traveled the 170,000



light-years directly to Earth. Some light headed away from the supernova at a slight angle to the direct path to Earth, hit interstellar dust clouds that were 470 and 1,200 light-years from the supernova, and was reflected toward Earth. This reflected light formed the light echoes, and the one-year delay in their arrival at Earth is due to the additional one light-year distance the echoes traveled.

Correction

The frequency of the millisecond pulsar PSR 1937+21 was incorrectly given in "On the Trail of Exotic Pulsars" by Gerrit L. Verschuur (December 1988) because of a typographical error. The correct frequency is 642 Hz.

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity. □

THE COSMOLOGICAL IMPERATIVE

by Eric Chaisson

Director of educational and public affairs at the Space Telescope Science Institute in Baltimore, Maryland

This century's remarkable astronomical discoveries — the vastness of time and the cosmos — can have a negative impact on humankind's perception of itself. How can we possibly matter in a universe billions of years older than we are and populated with objects that render us microscopic?

From another point of view, however, life, especially intelligent life, is as significant a part of the cosmos as galaxies and stars. From a perspective that encompasses the many varied changes in the assembly and composition of energy and matter over the entire existence of the universe — a perspective I call cosmic evolution — life plays an integral role in cosmology.

Cosmic evolution includes all aspects of evolution: particulate, galactic, stellar, planetary, biological, and cultural. What Darwin did for plants and animals, cosmic evolution does for all things. And if Darwinism started a revolution by freeing us from the belief that humans basically differ from other life forms, then cosmic evolution is destined to extend that intellectual revolution by releasing us from the idea that matter on Earth and in our bodies is different from the matter in stars and galaxies.

The universe has evolved through three major epochs. We can specify physical conditions that prevailed within the first second of existence. Most of the energy in the early universe took the form of radiation, not matter. For the first few hundred centuries energy reigned supreme over matter. All space was irradiated with light, x-rays, and gamma rays, guaranteeing a structureless and highly uniform blob of radiation. This was the Energy Era.

An event of insuperable significance must have occurred when subatomic matter began to coagulate within the otherwise chaotic state of primal energy extant shortly after the universe began. This emergence of matter as the dominant constituent in the form of galaxies, stars, and planets is the second era of cosmic evolution, the Matter Era.

I once regarded the onset of the Matter Era as the pre-eminent event of all time. But we can now identify another fundamental transformation, one that occurs when technologically competent, intelli-

gent life arises, in turn, from matter.

With the onset of technological intelligence on our planet and perhaps on others as well, sentient beings learn to manipulate and dominate matter, much as matter evolved earlier to govern energy. This change heralds a whole new era — the Life Era.

After more than 10 billion years of cosmic evolution the dominant species on planet Earth — namely we human beings — are now partly usurping the role played by inanimate nature, for we have become the agents of change. The physicist unleashes the forces of nature, the biologist experiments with the structure of genes, the psychologist influences behavior with drugs. To use a cliché that is true as never before, life is now taking matter into its own hands.

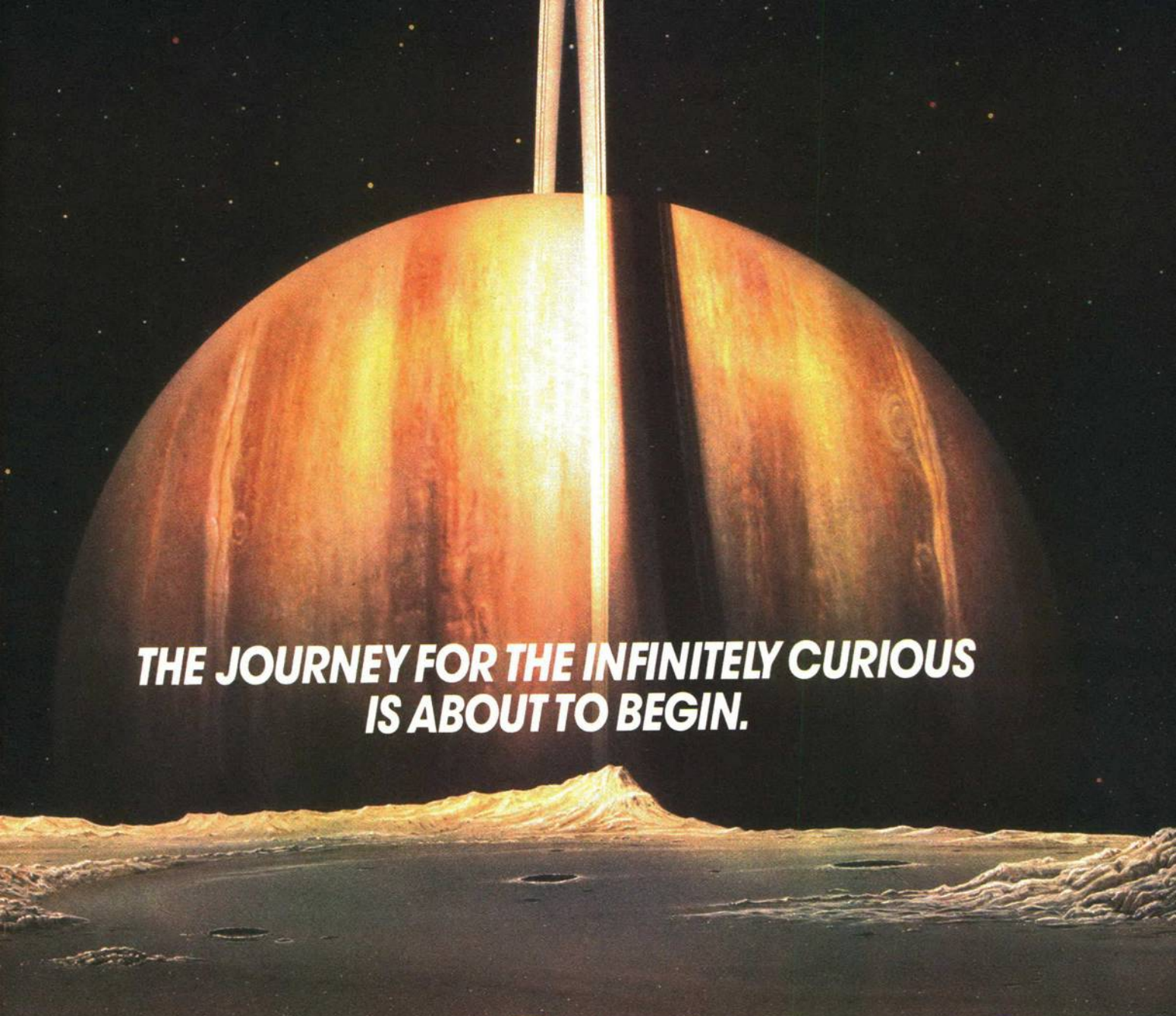
Our generation is now participating in an astronomically significant transforma-

Human actions are now an important part of cosmic evolution.

tion, a second great change in the history of the universe. And if we are now alone as an advanced life form in the universe, then we humans are contributing uniquely to the development of a new realm in the history of the cosmos. Human actions have now become just as much a part of evolution as the impersonal movements of atoms or galaxies.

We must now take an active role in the process of evolution. This role must begin with a collectively recognized set of ethics suited to the preservation of all humankind. We must now transcend the Darwinian principle of natural selection and embrace a loftier standard that I call "the principle of cosmic selection": Those technological civilizations on any planet that recognize the need for, develop in time, and fully embrace a global ethics will survive, and those that do not will not.

Cosmic evolution should become the guiding paradigm for our time. This is a positive and realistic view despite the apocalyptic issues confronting us on Earth. To employ cosmic evolution as an intellectual and practical guide toward the Life Era is to think in dynamic rather than static terms, to realize the evolutionary roots of human values, and to renew a sense of hope. □



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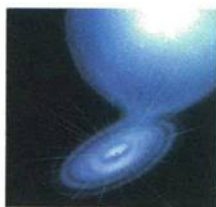
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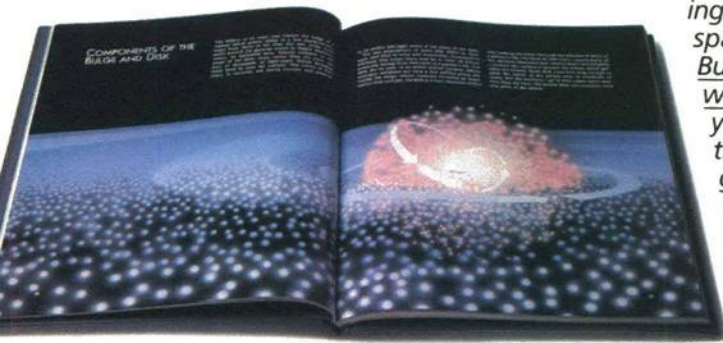
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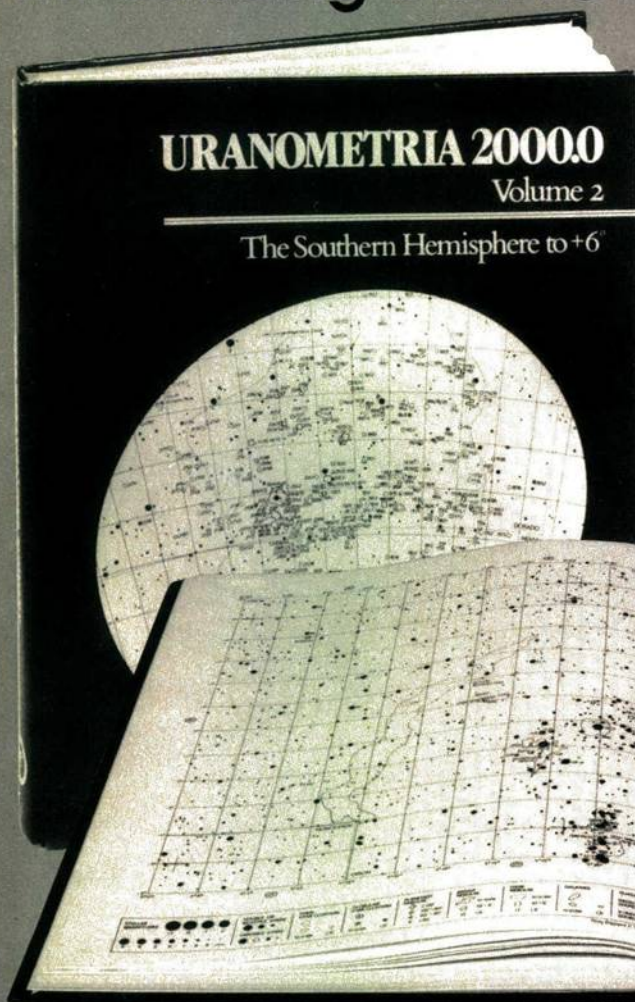
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PULSAR ERODING COMPANION STAR

Astronomers have discovered the first millisecond pulsar — a neutron star spinning hundreds of times per second — known to undergo regular eclipses by a tiny companion star. Furthermore, the intense outward flow of matter from the rapidly spinning pulsar will eventually cause the companion to evaporate, leaving only the pulsar. Such a process might explain why the majority of millisecond pulsars are companionless.

In a paper published in *Nature* last year, Andrew Fruchter, Daniel Stinebring, and Joseph Taylor, all of Princeton University, announced that the millisecond pulsar, PSR 1957+20, is a member of an eclipsing binary system — two stars with orbits that cause them to eclipse each other as viewed from Earth. Brightness variations in the 19th-magnitude pulsar indicate that the pulsar is being eclipsed by a companion star once each orbit for about fifty minutes.

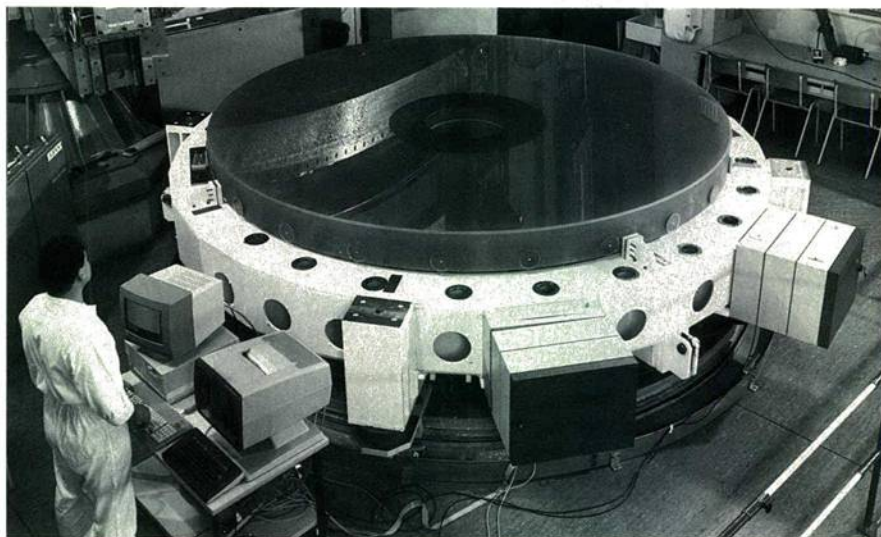
Fruchter and his colleagues were able to apply the laws of physics to the orbital period and size of the binary system in determining the mass of the companion. Given a pulsar mass of 1.4 solar masses, which is typical of most neutron stars, the mass of the companion is surprisingly low, only a small percentage of the Sun's mass.

Further study of the pulsar's period, however, revealed something even more fantastic. A few minutes before and twenty minutes after each eclipse the pulsar's signal is delayed, as if something is inhibiting the emission. The astronomers believe the delay is caused by the signal passing through a cloud of ionized gas surrounding the companion.

The size of this cloud — 650,000 miles across — indicates that most of the material lies outside the gravitational influence of the tiny companion, which is estimated to be about 20,000 miles in diameter. This strongly suggests that the cloud is being blown outward by a pulsar "wind," a flurry of electrons whipped out at near light speeds by the pulsar's whirling magnetic field.

The cloud associated with PSR 1957+20 probably consists of material boiling off the small companion star in cometlike fashion. In fact, a decrease in the density of this boiled-off gas on the trailing side of the eclipse is interpreted as the "tail" of the cloud.

Fruchter believes the PSR 1957+20 system may explain why companions are not commonly observed orbiting millisecond pulsars: the companions eventu-



AN ACTIVE OPTICS MIRROR, like the 3.58-meter mirror for the European New Technology Telescope, is computer optimized to provide the sharpest possible images at all times.

ally evaporate. Fruchter and his colleagues estimate that the companion to PSR 1957+20 is losing material at a rate that will cause it to disappear in about a billion years.

NEW TECHNOLOGIES FOR TELESCOPES

New industrial technologies are changing the way astronomers build telescopes. New manufacturing methods allow glassmakers to pour larger glass disks, new materials allow ultralight metal mirrors to be built, and computer control provides more precise optics than ever before. The result is lighter optics, bigger telescopes, and lower costs.

In September 1988 the German firm Schott Glaswerke of Mainz contracted with the European Southern Observatory (ESO) to produce the four 8.2-meter glass mirrors for the Very Large Telescope ESO plans to build. With the aid of a new technology called spin casting (see *AstroNews*, October 1988), the German glassmaker will pour 10 cubic meters of low-expansion Zerodur glass into a rotating mold to a depth of 18 centimeters (7 inches).

Centrifugal force shapes the surface of the spinning blank, minimizing the amount of material to be removed during subsequent grinding. After they are ground and polished to high precision, the mirrors will be used in the four telescopes that make Europe's Very Large

Telescope array. The \$200 million telescope is scheduled for completion in 1998 and will have the light-gathering power of a 16-meter instrument.

Meanwhile, a team of engineers and opticians headed by Dan Vukobratovich at the University of Arizona has designed and built a better *small* telescope. The first lightweight, metal foam-core telescope systems feature experimental 12-inch mirrors that weigh 4.5 pounds apiece. (A conventional glass mirror of the same size weighs 20 pounds.) The entire 12-inch telescope weighs 10 pounds. "You can carry it in one hand," said Vukobratovich.

Metal foam-core mirrors are made by bonding two metal faceplates to an inexpensive metal foam that has been machined to the desired curve. The faceplates are covered with a scratch-resistant nickel surface. After the optical figure has been polished in, the surface is coated with an aluminum film, just as glass mirrors are.

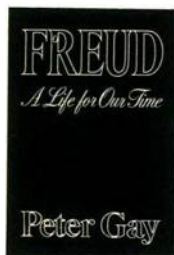
"Right now it's still developmental," Vukobratovich reported, "but it's a very exciting technology." The new technology will have immediate application in the commercial market for telescopes, telephoto lenses, and defense and communications systems.

In large professional telescopes the advent of "active optics" marks yet another breakthrough for astronomers. An active optics telescope monitors the quality of its image and automatically

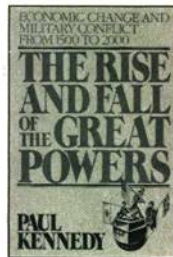
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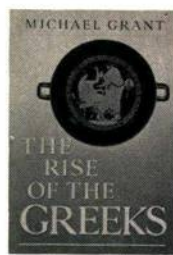
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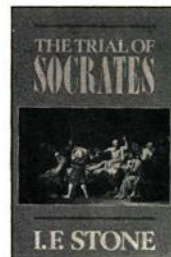
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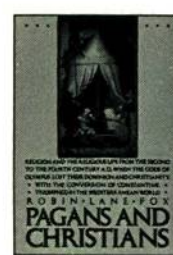
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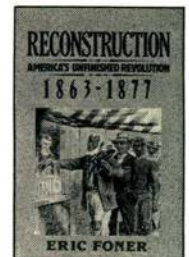
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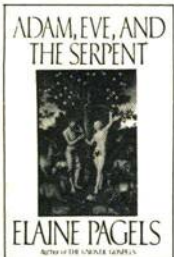
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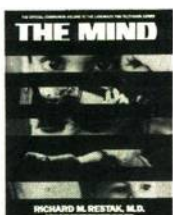
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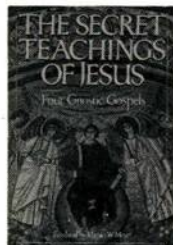
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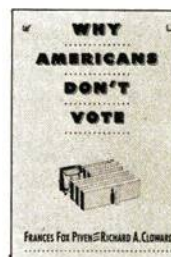
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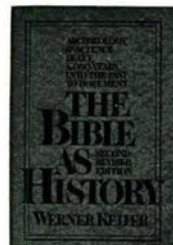
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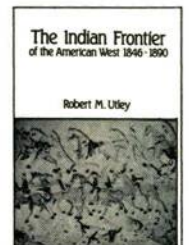
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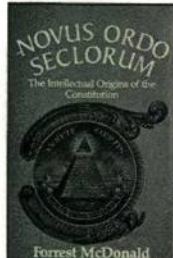
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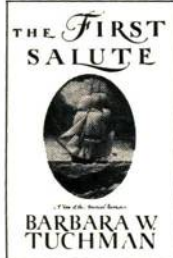
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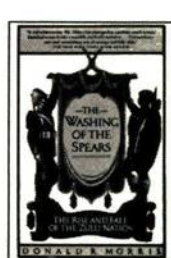
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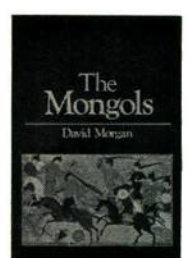
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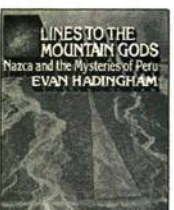
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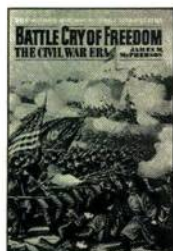
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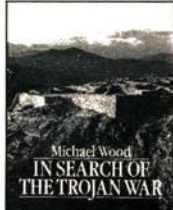
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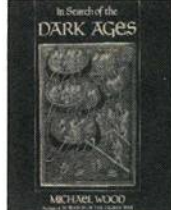
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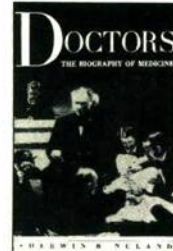
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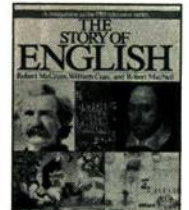
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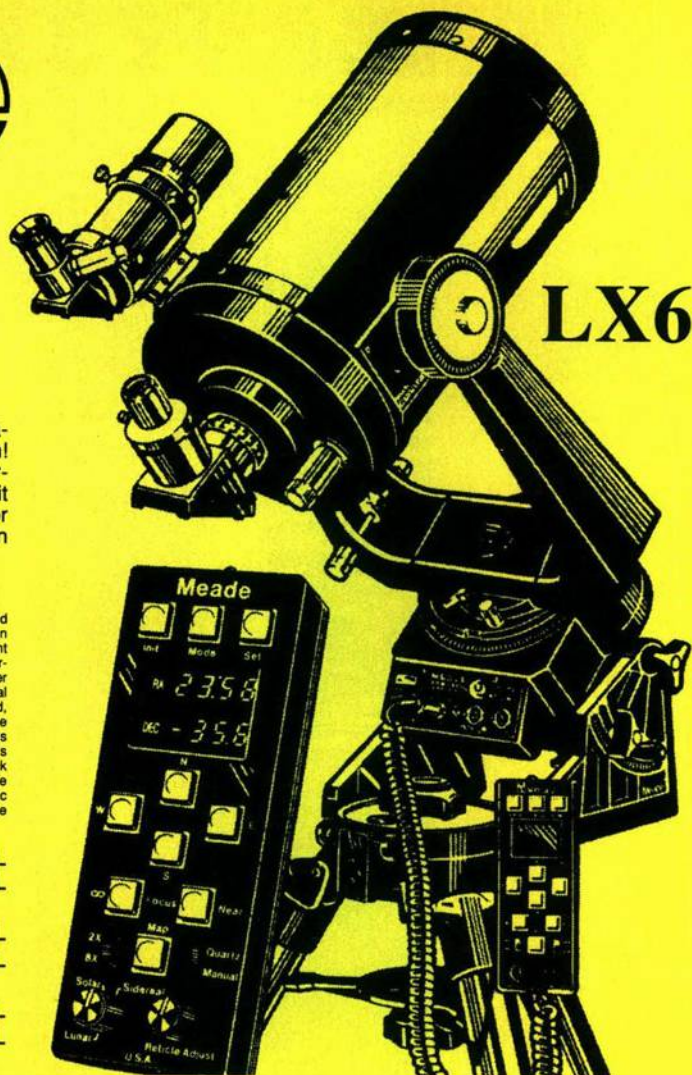
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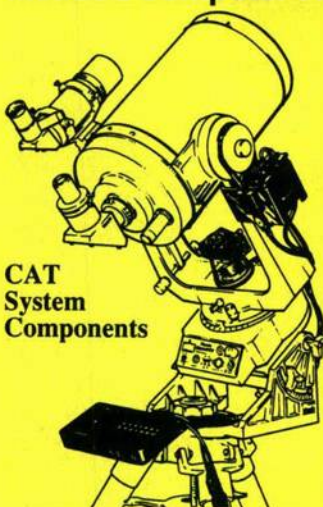
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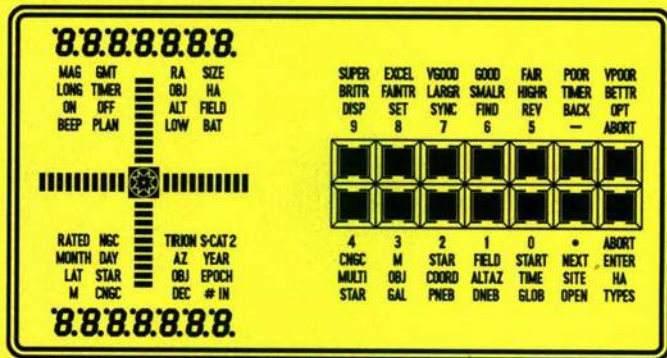


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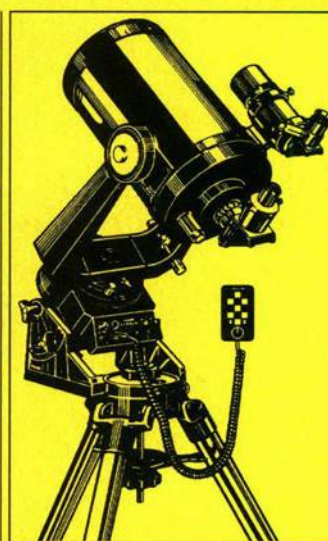
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Specs: 2080/LX5 and 2120/LX5: Complete 8" A (2080/LX5) or 10" A (2120/LX5) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz micro-electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; DC battery-pack (batteries not included) with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.



included with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.

2080/LX5, MCOG, Wedge, Tripod (as above) ..	(List: \$ 3,800)		CALL
2120/LX5, MCOG, Wedge, Tripod (as above) ..	(List: \$ 5,400)		CALL

FREE FREIGHT! (UPS Ground) for the LX5's above

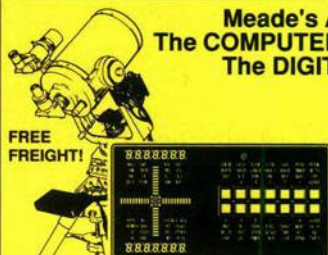
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Specs: 2080/LX3 and 2120/LX3: Complete 8" A (2080/LX3) or 10" A (2120/LX3) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; large 8x50mm viewfinder; 1.25" visual back (eyepiece holder); 1.25" prism-type star diagonal, anti-reflection coated; 25mm (80x or 100x) MA eyepiece, 1.25" barrel; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; quartz micro-electronic sidereal-rate drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; 25 ft. DC power cord with cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level and magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

2080/LX3, MCOG, Wedge, Tripod (as above) ..	(List: \$ 3,520)		CALL
2120/LX3, MCOG, Wedge, Tripod (as above) ..	(List: \$ 5,200)		CALL

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Individual System Pricing:			
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CAT Sys., for 2080, 2120, C8 or C11	(List: \$ 1,990)		CALL
CAT-COM, for 2080, 2120, C8 or C11	(List: \$ 2,290)		CALL
Package Pricing (Electronics System purchased at same time as its telescope):			
DSC Sys., for 2080, 2120, C8 or C11	(List: \$ 700)		CALL
CAT Sys., for 2080, 2120, C8 or C11	(List: \$ 1,990)		CALL
CAT-COM, for 2080, 2120, C8 or C11	(List: \$ 2,290)		CALL

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corrects it. With the successful completion of the 3.58-meter primary mirror for ESO's New Technology Telescope, astronomers will have access to near-perfect telescope mirrors.

The NTT mirror blank is only 40 percent as thick as a conventional blank, but a computer system monitors and corrects distortions in the mirror by pressing seventy-five computer-controlled levers on the back of the mirror to slightly bend the mirror. In this way astronomers expect image quality three times better than the best previously achieved and expect to maintain this quality continuously during operation. The resulting telescope is lighter and more precise.

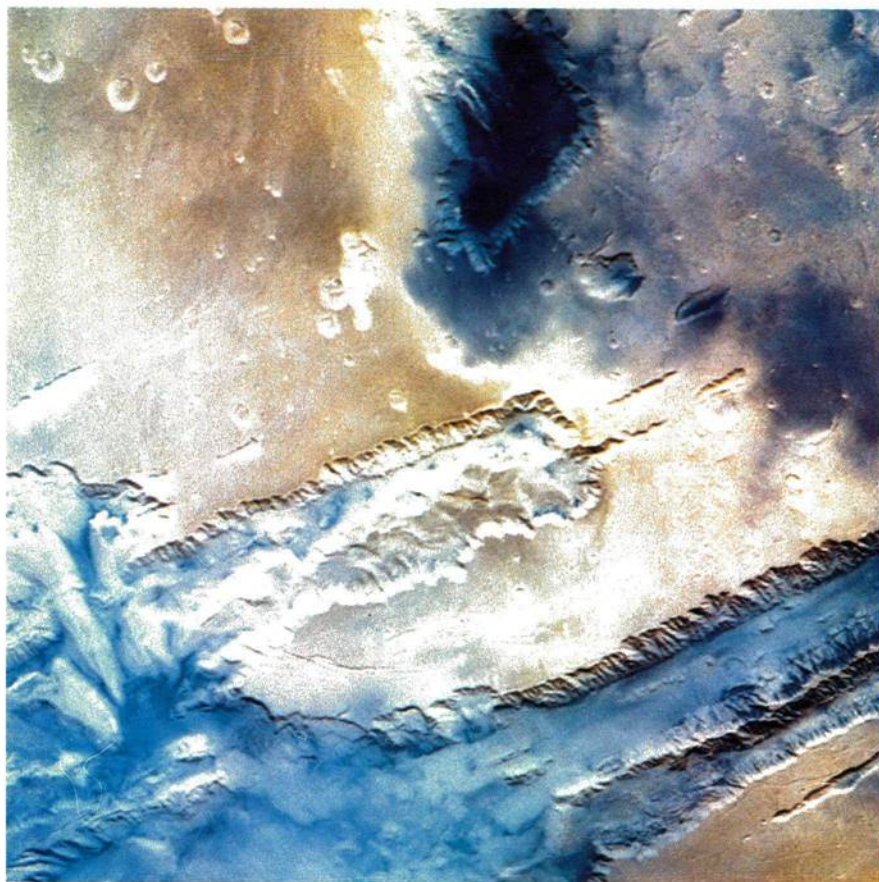
With the active optics turned on, the 3.58-meter mirror has an exceptionally smooth figure. Among the world's large telescopes, only the mirror of the 2.4-meter *Hubble Space Telescope*, awaiting launch in December 1989, exceeds the NTT mirror in quality. The NTT is expected to go into operation for astronomical research in early 1989.

VOLCANIC ASH EXPOSED IN MARTIAN CANYONS

A dark layer of material exposed on some Martian canyon floors may be part of a widespread volcanic ash deposit more than a kilometer thick, according to a report by Paul Geissler of the University of Arizona's Lunar and Planetary Laboratory, together with R. B. Singer of the LPL and B. K. Lucchitta of the U.S. Geological Survey. They studied the spectral reflectance of the outcrops of dark material that are exposed in the walls of Coprates Chasma (a part of Valles Marineris) and that appear to underlie neighboring depressions.

Based on comparisons of laboratory reflectances with those of the Martian surface observed by the *Viking Orbiter 1* craft, the researchers conclude that a relatively unaltered or slightly oxidized basaltic glass has the optical properties that fit the observations best. The layer in the wall of Coprates is at least one kilometer thick. The researchers think the dark material could be loosely compacted ash because of the way it erodes in the canyon and by what look like wind streaks radiating from Juventae Chasma, the dark triangular region in the upper center of the photo.

The streaks fall generally in the direction of the prevailing winds, and this portion of Mars lies just to the east of the great Tharsis volcanic province, home to Olympus Mons and three other large volcanoes.



MARTIAN VOLCANIC ASH (bluish black in this false-color image) is exposed in many places in Valles Marineris and may underlie the entire region.

GREEN BANK'S 300-FOOT RADIO TELESCOPE COLLAPSES

One of the world's most powerful radio telescopes, the 300-foot dish at the National Radio Astronomy Observatory's facility in Green Bank, West Virginia, collapsed suddenly on November 14 during an evening observing run. The telescope was a total loss. Observatory officials fear the accident may set radio astronomy research back years.

The cause of the collapse was not immediately known, and George A. Seielstad, assistant director of the observatory, said he did not know how long the investigation would take. "It may even be impossible to determine," he said. "The whole telescope just came down and the question is 'what went first that triggered everything else to go?'"

Built in 1962, the 300-foot radio telescope was instrumental in a number of major discoveries, including gravity waves and the detection of the pulsar in the Crab Nebula. The radio telescope could scan large areas of the sky for radio-emitting objects, up to 100,000

radio objects at a time. Objects of interest could then be investigated in more detail by other radio or optical telescopes.

"It was a unique telescope," said Seielstad. "The data it provided were so fundamental because that was the first step in almost every investigation. The follow-up detail conducted by other radio telescopes depended on this first step."

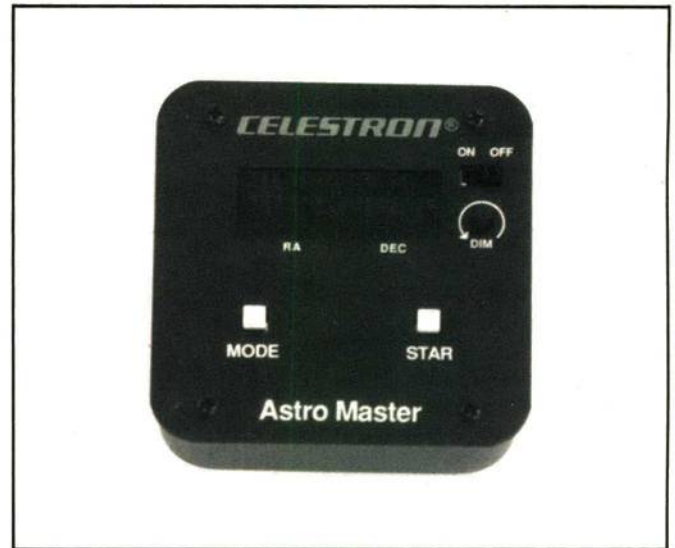
Seielstad said the loss of the 300-foot radio telescope leaves a void in research astronomy that won't be filled in the near future. "The telescope was scheduled through January 1989, and I have enough proposals on file that probably would have occupied most of 1989," said Seielstad. "The demand was very high and I don't know how it will be met now. Some of that work will just stop because there's no way to do it elsewhere. It's not easy to say that another telescope will be able to pick up the slack primarily because Green Bank is in the 'national radio quiet zone,' and there is a lot less interference here compared to other telescope sites around the world. You can't just say, 'I'd like to make a major radio survey of the sky at some frequency with

ASTRO MASTER—

Digital Setting Circles for Super Polaris Mounts

Whether attempting deep sky photography or visual observing, the new digital setting circles for Super Polaris telescopes will make it easier to find the object you're looking for. The Astro Master is a digital display setting circle designed specifically for the Super Polaris mount. The unit is small, lightweight and easy to attach. The Astro Master lists right ascension and declination coordinates. Red digital read-out display preserves dark adaptation. Use the Astro Master by itself, without any motor, or with the optional Super Polaris motor drive or the Sky Sensor computer. If you are not using a motor drive, the system will keep track of R.A. coordinates for you.

20 bright stars in memory for alignment. Once aligned, all you do is look up the coordinates of the object you want to observe, and move the



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- Variable brightness read-out
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Looking for that perfect accessory to make guiding during deep sky astrophotography easier? Then discover astrophotography's best kept secret—the **Illuminated Projection Reticle!**

The Illuminated Projection Reticle does exactly what its name implies—it projects an illuminated guiding reticle onto an eyepiece. What eyepiece? Any eyepiece you choose. Unlike normal guiding eyepieces, which are fixed focal length and have a built-in reticle, the Illuminated Projection Reticle

allows you to select the eyepiece type and power you want to guide with.

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So why make things more difficult than they are? With the Illuminated Projection Reticle you can spend more time photographing and less time getting ready.

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a wide bandwidth, 'because you're liable to have interfering signals in that band at these other locations.'"

However, even while the twisted remains of the scope were being analyzed by engineers, there was hopeful talk of building a replacement. "That's my goal now," said Seielstad. "We were looking into the concept of building a new telescope anyway, and now we're going to try and accelerate that by saying, 'turn this disaster into a good thing by producing a new and better telescope.'"

MOUNT GRAHAM OBSERVATORY CONTROVERSY SETTLED

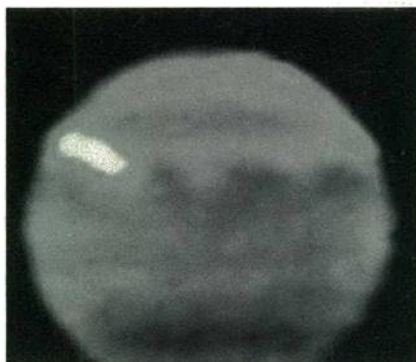
After more than four years of contention, a new international observatory will be built on an 11,000-foot peak of Mount Graham in southeastern Arizona, despite objections by environmental groups that the telescopes will harm the habitat of the endangered Mount Graham red squirrel. The Arizona-Idaho Conservation Act of 1988, which became law in November, clears the way for the University of Arizona to begin construction of three telescopes.

The controversy centered on the U.S. Forest Service's biological studies of how building an observatory on Mount Graham would affect the red squirrel. The University of Arizona originally wanted to build up to ten telescopes at two sites on Mount Graham. But a preliminary Forest Service assessment of the environmental impact recommended against development of such a large site.

Mount Graham was chosen by the University of Arizona as the site for a multi-instrument observatory based on a survey of all potential astronomical sites in the southwestern United States. Mount Graham best satisfied the requirements — clear weather, dark skies, low water vapor — that are critical to the operation of the advanced telescopes planned for the observatory.

Construction on the Max Planck submillimeter telescope is expected to begin on Emerald Peak this spring, after a new access road to the site is built. Work will begin on the Vatican Advanced Technology Telescope, an optical/infrared telescope, shortly afterward. The third telescope, the Columbus Project, a binocular telescope with two 8-meter mirrors, will be started in about two years.

Four additional telescopes may be built on Emerald Peak, depending on the effect of the first three telescopes on the red squirrel. Environmental groups opposing telescopes on Mount Graham plan to fight the four additional telescopes.



A MYSTERIOUS "HOT SPOT" on Jupiter appears as a bright bar at the 10 o'clock position on the Jovian disk in this infrared image.

WARM SPOT ON JUPITER

An unexplained warming last September in part of Jupiter's upper atmosphere was reported by a team of six astronomers led by Glenn Orton of the Jet Propulsion Laboratory. The team took images of Jupiter at an infrared wavelength of 7.8 micrometers, which is characteristic of methane molecules that reveal stratospheric temperatures. Taken last September 26 at 13:06 UT when the

central meridian was 312° , the best image shows the warm feature as a bright bar at the 10 o'clock position on Jupiter's disk (the photo has north at top).

The feature's temperature of 133 kelvins is roughly 5 kelvins warmer than the rest of the Jovian disk. It spans about 15,000 kilometers and runs from 15° north latitude to 30° . "It's unclear at this point why this region of the stratosphere has warmed up so quickly," Orton says. "Particles could have fallen into the atmosphere, absorbed sunlight, and heated it up — or it could be a part of the stratospheric wind dynamics."

The warm spot appears to be part of a series of features in the northern hemisphere that are separated by about 30° to 40° of longitude. Bright spots and elongated arclike features were detected in the infrared for the first time in December 1987 in Jupiter's middle northern and southern latitudes. The origin of these features is not understood, nor are there any counterparts at visible wavelengths.

Besides Orton, the team included David Anthony and John Caldwell of York University, Toronto, and James Friedson, Ian Avruch, and Michael Malcolm of JPL.

Space News

U.S./SOVIET COOPERATION GROWING

The United States and the Soviet Union have taken another step toward working together in the exploration of the solar system. High-level delegations of space scientists and engineers from both countries met last November in Washington to continue discussions begun in 1987 on cooperating on each other's current solar system missions. Although these meetings have not produced plans for any major joint missions, they are fostering increased cooperation between the space science programs of the two superpowers.

This was the second meeting of a joint working group on solar system exploration established by an agreement signed by the United States and the Soviet Union in April 1987. (See "Superpower Pact Links Initial Mars Missions" by Stephen Cole, November 1987.) That agreement spelled out specific space science projects the two countries would cooperate on.

As a result of the agreement, the United States has been helping to track the Soviet

Phobos mission to Mars with its worldwide network of antennas, the Soviets have given U.S. scientists data from their *Venera* missions to Venus, and both countries have invited each other's scientific communities to become involved in their current missions.

At the November meeting the two delegations compared notes on their plans to return to the Martian surface. Representatives of NASA and the Soviet Academy of Sciences exchanged their plans for Mars rover and sample-return missions. The Soviets have selected four possible landing sites for such a mission, and they requested U.S. maps and radar data on these areas.

Both sides also discussed the exchange of flight hardware and instruments on future solar system missions. The U.S. *Mars Observer* mission, scheduled for launch in 1992, may carry a Soviet receiver to relay data from the balloon experiments the Soviets are planning for 1994. (A decision is expected in March.) The Soviets offered to carry U.S. scientific

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"... so quick you really *can* observe 100 objects an hour, as the ads say ... If you prefer to spend your time observing deep-sky sights rather than hunting for them, then the CAT is ideal." — *Sky & Telescope*, November, 1987.

"... the CAT is a true time saver, a device that can show hundreds of objects per night ... the payoff is an automated, self-guided tour of the universe." — *Astronomy*, December, 1987.

What it is: The Meade CAT ("Computer Aided Telescope") system is a revolutionary telescope accessory that leads Schmidt-Cassegrain telescopes from object to object, in seconds. The graphic display on the CAT's console enables the observer to locate any object in the CAT's 8,199-object memory within, literally, 5 to 10 seconds or less.

How it works: Included with the CAT are 2 precision optical encoders that mount on the telescope and sense the telescope's position in RA and Dec; the encoders permit the location of even the most obscure objects with 25 times the precision of standard setting circles. Using the CAT's large, red-illuminated crossline display, the observer manually moves the telescope to the position dictated by the crosslines. The CAT unerringly positions the desired object precisely in the center of the telescopic field. In addition, digital readouts on the display console continuously display R.A. and Declination.

Object Database: Included within the CAT's computer memory database are the positions of 8,199 objects — *virtually every object of interest in the entire celestial sphere, North and South:*

- ☐ **7,840 Deep-Space Objects**, including all 110 Messier objects, plus 7,730 other objects contained in the Computerized New General Catalog (CNGC) — galaxies, nebulae, star clusters, objects of every description in the sky.
- ☐ **351 Bright Stars**, used primarily as CAT reference objects, including 100 interesting double and multiple stars.
- ☐ **8 Major Planets:** The positions of all 8 major planets are included in the CAT's

memory, a feature not available on any other computerized telescope system. In seconds you can locate Mercury, even in bright twilight; observe Uranus and Neptune; or photograph the day-to-day motion of 14th-magnitude Pluto. The CAT enables the positioning of these and the other major planets in the center of the field, *easily and rapidly*.

The Meade CAT attaches in minutes to Meade and other brands of Schmidt-Cassegrain telescopes and may be adapted by the user to other types of telescopes as well.

Models and Pricing

CAT #9000: for all Meade 2080 models	\$1495
CAT #9008: for Meade 2080/LX6	1495
CAT #9001: for all Meade 2120 models ..	1495
CAT #9010: for Meade 2120/LX6	1495
CAT #9003: for C8 fork-mounted models	1495
CAT #9005: for C11	1495

The CAT, shown on a Meade Model 2080/LX5.

NEW!

Digital Setting Circles for your Schmidt-Cassegrain!



Meade Digital Setting Circles utilize the high-technology of the CAT, but without the CAT's massive object database and other features, at a significantly lower price. Compare these specifications:

4 Operating Modes: Depress the "Mode" button sequentially and obtain:

- Mode 1:** reads out the Local Time and Sidereal Time on the 2 readout registers.
- Mode 2:** reads telescope Right Ascension and Declination. R.A. reads out to a precision of 1-min., Dec to 0.1°.
- Mode 3:** enables a digital timer for timing astrophoto exposures.
- Mode 4:** turns both registers "Off."

Optical Encoders: Meade Digital Setting Circles utilize Hewlett-Packard optical encoders for the highest level of precision and sensitivity. The encoders attach in minutes to the polar and Dec. axes. The readout unit mounts onto the telescope's rear cell, where it is *continuously visible from the eyepiece observing position as you move from object to object*.

Models and Pricing

DSC #9060: for all Meade 2080 models	\$495
DSC #9061: for all Meade 2120 models	495
DSC #9063: for C8 fork-mounted models	495
DSC #9065: for C11	495

Warranty: Every Meade CAT and DSC unit is covered by a 3-year warranty on parts and labor.

For further information: Send for your free copy of Meade Bulletin CAT/DSC, or send \$3.00 for the complete Meade **General Catalog #88C**. The 75-page CAT Instruction Manual is available at \$5.00.

Better still, call or visit your authorized Meade dealer; he'll be glad to answer any questions on the Meade CAT and DSC's—two of the most exciting and revolutionary telescope accessories ever developed.



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instruments aboard all of their Mars missions planned for the 1990s, and the United States proposed that the Soviets do the same on the *Cassini* mission to Saturn and the *Comet Rendezvous/Asteroid Flyby* mission.

"This meeting was exceptionally productive," said Geoffrey Briggs, director of NASA's solar system exploration division and co-chairman of the U.S. delegation. "It promises very well for the future."

MAGELLAN BACK ON TRACK AFTER MINOR FIRE

A small fire that broke out while NASA's *Magellan* spacecraft was undergoing testing at Kennedy Space Center will not delay the scheduled launch of the mission to Venus this spring.

The October 17 fire was caused by an electric short that occurred when a technician inadvertently inserted a test battery connector into a wrong socket in the spacecraft. The insulation on the cable leading back to the battery burned causing minor smoke damage to the spacecraft, which was only partly assembled at the time.

The resulting cleanup and retesting of the spacecraft took ten days from *Magellan's* already tight schedule. The lost time was expected to be made up by January, when the spacecraft is joined to the Inertial Upper Stage booster that will propel it from Earth orbit to Venus this April.

SOVIET SPACE AGENCY OUTLINES SHUTTLE PLANS

The Soviet Union's new space shuttle, which completed its maiden unmanned flight on November 15, will be primarily used to maintain, repair, or recover satellites in orbit, said the director of the Soviet commercial space agency.

In comments made at a Moscow news conference on the eve of the shuttle launch, Alexander Dunayev, chief of Glavcosmos, also stated that the Soviet Union intends to build a fleet of several reusable shuttles but that shuttle launches would not exceed four each year.

According to Dunayev, the Soviet shuttles will not be used as all-purpose launch vehicles, as the U.S. shuttle is, because conventional rockets can handle most payloads at a fraction of the cost. Only in exceptional cases, Dunayev said, would spacecraft be carried into orbit by their shuttle.

Glavcosmos has not yet announced dates for the next shuttle flight or for the first manned flight.

Amateur News

PERKINS HOSTS MARS WATCH

Perkins Observatory in Delaware, Ohio, opened to a large group of stargazers for the first time in its sixty-four-year history last October. The reason was Mars: Over a thousand residents of Columbus and surrounding communities saw the Red Planet as it pulled away from opposition on October 13, 14, and 15.

Perkins Observatory is co-administered by Ohio State and Ohio Wesleyan universities. Once home to the largest telescope in Ohio, Perkins now holds a 32-inch f/17 telescope that appears small because of the oversized dome that surrounds it. Prior to 1961, the dome contained a 69-inch reflector. Astronomers moved the reflector to Lowell Observatory in Flagstaff, Arizona, because of the better observing conditions there.

The Mars watches were a result of the cooperation among three astronomy groups. Bob Bunge and Tom Burns of the Columbus Astronomical Society approached the Ohio State University Astronomy Department and Ohio Wesleyan University with the idea. The universities liked the idea so much they donated time on the 32-inch telescope over three nights. Columbus Astronomical Society members provided fifteen telescopes ranging from 3 to 17.5 inches in anticipation of crowds.

"We were delighted to have pulled off such a fine Mars program," said Bunge. "With more than one hundred members in central Ohio, our club organizes a large number of observing programs in local parks. This year alone we have shown thousands of people their first views of the stars."

ASTRONOMICAL LEAGUE STARTS MEMBER-AT-LARGE PROGRAM

The Astronomical League, the nation's confederation of over 150 astronomical societies, recently started a member-at-large program. Previously Astronomical League membership benefits were available only to members of clubs affiliated with the league. Now, however, anyone can join.

For an annual fee of \$25 each member-at-large receives a subscription to the league's quarterly *Reflector* newsletter, a copy of the annual convention proceedings, discounts on astronomy books, a subscription to the *Griffith Observer*, *Star Date*, or the *Abrams Planetary Star Chart*, and other benefits. For more information, contact Linda Sensenig, 345 Douglass Street, Wyomissing, PA 19610. □



BIG SCOPE VIEWS OF MARS awaited those who peeked through the 32-inch telescope at the Perkins Observatory Mars watches last October in Delaware, Ohio.

The LX6 Revolution is here!

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Meade 228 Brass Refractor \$379

This solid brass refractor looks great in home or office. Critically sharp image with full 2.4" objective and quality Meade eyepieces. Simple yoke-style altazimuth mount allows quick and easy positioning. Includes .925" star diagonal, 2 eyepieces, 5x24 finder, full-size adjustable tripod, and brass hardware.

Meade MTS-SN6 System \$739

Fast 6" f/5 Schmidt-Newtonian telescope is great for wide-field exploration. Sharp, coma-free viewing and photography. Complete with AC clock drive, setting circles, observatory pier mount, eyepiece, and multi-coated optics.

Meade 314 \$789

Distinctive solid brass 3.1" refractor has convenient altazimuth mount with precision slow motion controls for easy land and sky viewing. An excellent addition to any home or office. Includes 1.25" star diagonal, Meade 25mm Modified Achromat eyepiece, 5x24 finder, and full-size adjustable tripod with dark finish and brass hardware.

Meade Digital Setting Circles (LX6) \$339

With the addition of the optional Meade Digital Setting Circles, finding exciting things to view and photograph has never been easier. Four separate modes provide sidereal time, local time, right ascension accurate to 1 min. and declination to 0.1 degree, and a digital timer for precise timing of astrophoto exposures. Available for all current Meade 2080 and 2120's, as well as fork mounted C8 and C11's.

Meade Digital Setting Circles (except LX6) . . . \$379



New! Meade CAT System \$1189

Increase your viewing time and enjoyment by taking out the guesswork...with Meade's new telescope accessory, the CAT (Computer Aided Telescope) system. With a database holding 8,199 objects, you may quickly locate all 110 Messier objects, 251 bright reference stars, 100 multiple stars, 8 major planets (including 14th magnitude Pluto), plus 7,730 other objects contained in the Computerized New Catalog! Available for all current Meade Schmidt-Cassegrains, and all fork-mount C8's and C11's. Please specify telescope.

Meade Series 4000 Eyepieces

Excellent eyepieces at a great price!

Super Plossl 6.4mm to 26mm	\$.74
Super Plossl 32mm or 40mm	\$.94
Super Plossl 56mm	\$1.59
Series 4000 2x Barlow	\$.71
Super wide angle 13.8mm	\$1.19
Super wide angle 18mm	\$1.29
Super wide angle 24.5mm	\$1.39
Super wide angle 32mm	\$1.97
Super wide angle 40mm	\$2.54
Ultra wide angle 4.7mm	\$1.39
Ultra wide angle 6.7mm	\$1.59
Ultra wide angle 8.8mm	\$1.98
Ultra wide angle 14mm	\$2.15

Accessories

Meade Off Axis Guider System \$159

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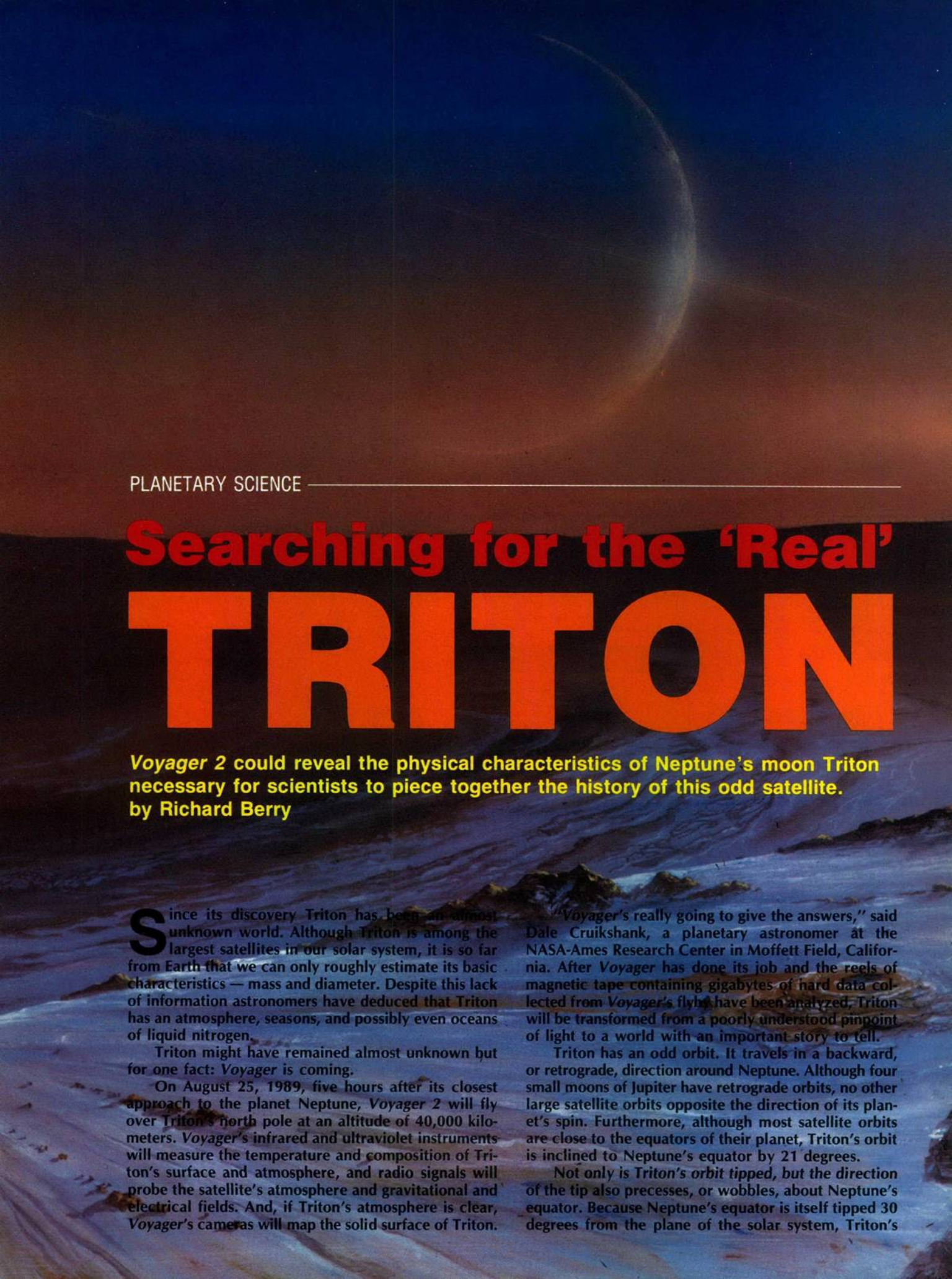
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PLANETARY SCIENCE

Searching for the 'Real' TRITON

Voyager 2 could reveal the physical characteristics of Neptune's moon Triton necessary for scientists to piece together the history of this odd satellite.

by Richard Berry

Since its discovery Triton has been an almost unknown world. Although Triton is among the largest satellites in our solar system, it is so far from Earth that we can only roughly estimate its basic characteristics — mass and diameter. Despite this lack of information astronomers have deduced that Triton has an atmosphere, seasons, and possibly even oceans of liquid nitrogen.

Triton might have remained almost unknown but for one fact: *Voyager* is coming.

On August 25, 1989, five hours after its closest approach to the planet Neptune, *Voyager 2* will fly over Triton's north pole at an altitude of 40,000 kilometers. *Voyager's* infrared and ultraviolet instruments will measure the temperature and composition of Triton's surface and atmosphere, and radio signals will probe the satellite's atmosphere and gravitational and electrical fields. And, if Triton's atmosphere is clear, *Voyager's* cameras will map the solid surface of Triton.

"*Voyager's* really going to give the answers," said Dale Cruikshank, a planetary astronomer at the NASA-Ames Research Center in Moffett Field, California. After *Voyager* has done its job and the reels of magnetic tape containing gigabytes of hard data collected from *Voyager's* flyby have been analyzed, Triton will be transformed from a poorly understood pinpoint of light to a world with an important story to tell.

Triton has an odd orbit. It travels in a backward, or retrograde, direction around Neptune. Although four small moons of Jupiter have retrograde orbits, no other large satellite orbits opposite the direction of its planet's spin. Furthermore, although most satellite orbits are close to the equators of their planet, Triton's orbit is inclined to Neptune's equator by 21 degrees.

Not only is Triton's orbit tipped, but the direction of the tip also precesses, or wobbles, about Neptune's equator. Because Neptune's equator is itself tipped 30 degrees from the plane of the solar system, Triton's



EXTREME SEASONAL CYCLES create a strange methane-ice landscape near the south pole of Triton in one scenario of what Neptune's large satellite might look like.

POSSIBLE TRITONS

No one knows which Triton *Voyager 2* will find orbiting Neptune. It may be a large body, dark in color, and wrapped in a clear atmosphere, or small, bright, and totally cloud-covered. *Voyager* will reveal "the real Triton" this August.



orbit is alternately presented edge-on and steeply inclined to the Sun as Neptune orbits the Sun and as Triton's orbit precesses.

Depending on where Neptune is in its orbit, the tilts of the planet and the satellite can add up or cancel each other out. When the tilts are added, the Sun shines on one pole of Triton for fifty years, which leaves the other pole in complete darkness. When the tilts cancel out, the Sun shines on Triton's equator for a hundred years.

The complex sequence of tilts gives Triton a changing cycle of very mild and very extreme seasons. The most extreme seasons occur at roughly 700-year intervals. "We're coming up on a 'major' summer in 2007," said Larry Trafton, a planetary astronomer at the University of Texas. "The hottest 'days' of summer on Triton may come five to ten years after that, depending on how much heat the surface holds."

Observational Finesse

The uncertainty over Triton's mass and diameter is astounding when put into human terms. If Triton were a person, it could stand anywhere between 4 feet and 6 feet 4 inches tall and weigh between 60 and 160 pounds. Although astronomers tend to think of Triton as 5 foot 2 and 100 pounds — 3,600 kilometers and 93 billion billion metric tons — there is little hard observational evidence for these estimates.

The mass of a satellite is measured by the gravitational pull the satellite exerts on the planet it orbits. As Triton swings in its orbit about Neptune, Neptune in turn pivots around the common center of gravity. To measure Triton's mass, then, astronomers monitor the motion of Neptune.

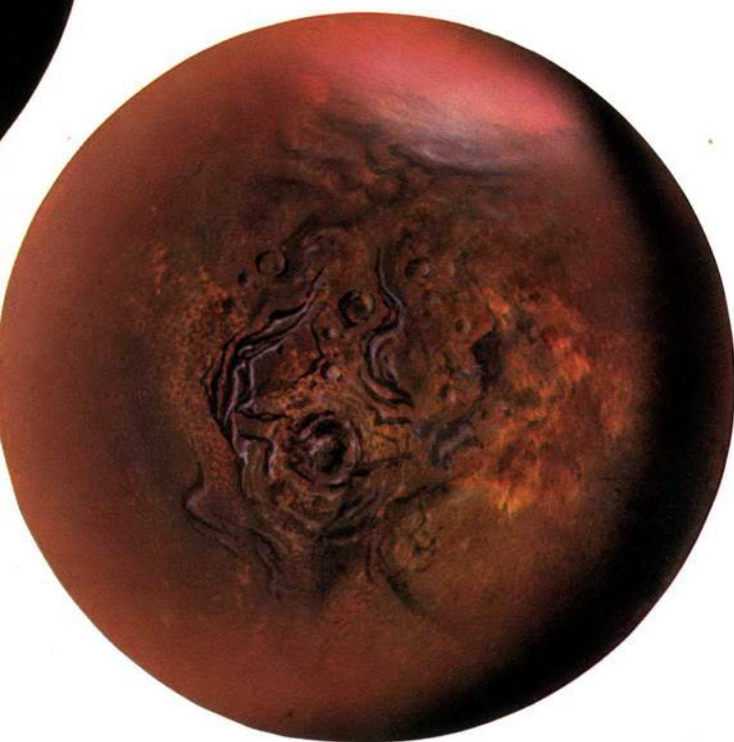
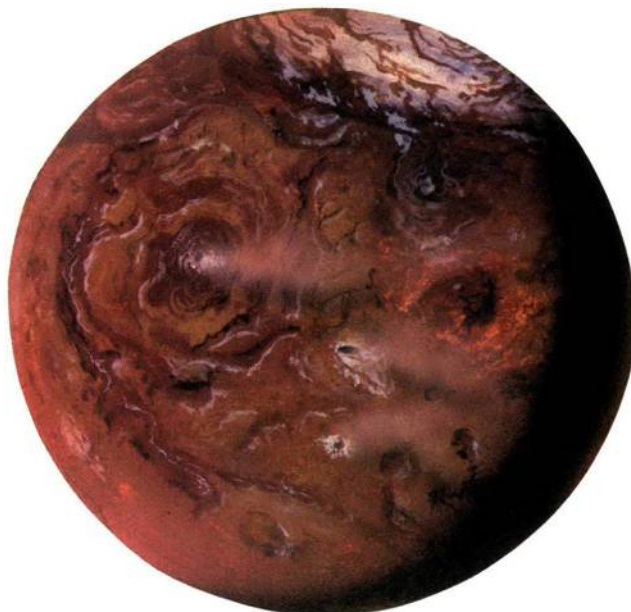
However, determining the tiny wobble Triton induces in Neptune's motion is an extraordinarily delicate task that is prone to a multitude of errors — and the last definitive study was done in 1943. It yielded a mass for Triton of 1/750 the mass of Neptune with an uncertainty half as large as the measurement itself. This determination is probably too high, but there is no better one to replace it.

Triton's diameter is equally iffy. Because Triton is too distant to show a measurable disk in an Earth-based telescope, astronomers try to estimate Triton's diameter from its brightness. If Triton were to reflect 40 percent of the sunlight that strikes it — typical of ice-rich satellites — it would be 3,600 kilometers in diameter.

But no one knows how much light Triton reflects. If Triton has bright frost deposits on its surface, it could be as little as 2,200 kilometers in diameter, although this would imply an unrealistically high density for Triton. Or, if dark hydrocarbon deposits cover its surface, Triton could be 5,000 kilometers in diameter.

"Observationally Triton is only a 14th-magnitude point of light," said Cruikshank, "so the number of people who have seen it can probably be counted on the fingers of two hands."

Among their accomplishments, those astronomers have discovered that Triton has an atmosphere. "The spectrum shows absorption bands of methane in the infrared," said Cruikshank. "There's no doubt about the presence of methane on Triton."



But there is considerable doubt about the physical state of the methane. Gaseous and solid methane both produce absorption bands. Although frozen methane on the surface could explain the spectrum, so could a gaseous methane atmosphere. However, if there's methane frost on the ground, there must be an atmosphere of methane gas over it. Methane ice is quite volatile: methane gas would evaporate from a methane ice surface until there was an atmosphere.

"We've also observed a band at a wavelength of 2.16 microns that we attribute to nitrogen," said Cruikshank. "We call this a tentative identification because we've based it on a single spectral feature."

Nitrogen is even more volatile than methane — about a thousand times more volatile. If Triton has nitrogen ice on its surface, it should have about a thousand times more nitrogen than methane in its atmosphere. If nitrogen is present, it will dominate Triton's atmosphere.

The amount of gas above a volatile ice, either methane or nitrogen, is exquisitely sensitive to temperature. "To double the atmospheric pressure, you only need a change in surface temperature of a degree or two," explained Trafton. "That's all it takes." Thus, Triton's ices would be very sensitive to seasonal variations in sunlight. During a long, hot maximum summer such as the one that peaks in 2007, the atmosphere could grow as Triton warms.

Observations of Triton's brightness support the idea of possible seasonal changes on Triton. In 1977 Otto Franz of Lowell Observatory measured Triton's brightness as the satellite rotated and found that Triton's brightness fluctuated by about 6 percent. Such variation is expected because bright and dark surface features are seldom uniformly distributed around a planet.

Ten years later, in 1987, Niel Lark of the University of the Pacific did CCD photometry of Triton and couldn't detect any brightness variation at all. What happened?

"If a haze layer formed in the last ten years, it would

Triton among the Voyager Moons



Among the moons of the solar system Triton may rank as one of the largest. Triton could be the third largest, after Titan and Ganymede, or as small as eighth largest.

explain the absence of variation," Cruikshank said. "But you would think haze would have made the whole satellite a little brighter, and the observations show it isn't brighter. The conclusion could be that Franz was wrong — those data were pretty rough — and that Triton never had a variation, or that a haze did form but that Triton has the same brightness as before, which is unlikely."

Cruikshank himself had observed changes in Triton's spectrum between 1980 and 1986. "The methane spectral features became more muted. That is consistent with the formation of haze or clouds in the atmosphere." The observations thus leave major questions for to answer.

Modeling Possible Tritons

"Basically we've got three plausible models of Triton, two of which include nitrogen on the surface and in the atmosphere," said Robert H. Brown, a planetary astronomer at the Jet Propulsion Laboratory. "Each of these models fits the data we have without serious contradictions."

"There's a cold Triton," Brown said, "with a thin nitrogen atmosphere, a little haze, and a frozen nitrogen surface and methane ice mixed in to explain the spectrum." This model of Triton has a cold surface temperature of 52 or 53 kelvins.

"Then there's a hotter Triton model with a thick, clear atmosphere, liquid nitrogen on the surface, maybe in oceans, and methane dissolved in the oceans to explain the spectrum. The surface temperature has to be above 63 kelvins. It takes a greenhouse atmosphere to explain this Triton."

"There's also a Triton with a hazy atmosphere caused by some constituent — not nitrogen — mixed in the atmosphere. To me this model is the least plausible

of the three," Brown noted.

Observationally it's impossible to tell which is the real Triton. Moreover, modeling Triton is far trickier than deciding which of three models — if any — is right. Triton could have the most extreme seasons of any body in the solar system. Its atmosphere could change greatly from season to season — or it could have no seasonal changes at all. It all depends on where the ice is.

"If its ice is in polar caps," observes Triton modeler Trafton, "then Triton gets complicated." Several meters of methane ice could evaporate from Triton's sunny pole as a major summer comes on, which would cause Triton's atmosphere to grow a thousand times in volume and reach a tenth of the atmospheric pressure on Earth. With a maximum summer coming in 2007, this Triton is what *Voyager* may see when it flies by.

Three hundred years from now, when Triton is having minimum summers and minimum winters, its equator will bask in sunlight. Both poles will be dark and cold. Under tropical conditions, ice at the warm equator will be sublimated and freeze on the cold poles. Triton would then look very different than it will in 1989.

"To have seasons," declared Trafton, "Triton has to have bare patches." If Triton were covered entirely with ice, there would be no seasonal variation at all. The sublimation that occurs in one place would be balanced by condensation in another place. As ice vaporized, the

AN HOUR AFTER CLOSEST APPROACH to Triton, *Voyager* may see sunlight glinting off nitrogen lakes and illuminating haze layers in Triton's atmosphere.



Pre-Voyager Data for Triton

HISTORICAL

Discoverer: William Lassell
Date of discovery: October 10, 1846

ORBITAL

Orbital period of Neptune: 165 years
Mean distance from Sun: 30.06 AU
Orbital period of Triton: 5.8768 days
Motion: Retrograde
Orbital radius: 354,290 kilometers
Inclination to equator of Neptune: 21°
Precession period: 637 ± 40 years

OBSERVATIONAL

Magnitude at opposition (V): 13.7
Color: B-V = 0.72 (yellow-orange)
Variation of light in orbit: 6% (1977)
Variation of light in orbit: <1% (1987)
Spectrum: Methane absorption
Possible nitrogen absorption feature

PHYSICAL

Mass: 9.3×10^{-4} Neptune
(9.3×10^{19} metric tons)
Diameter: 3,600 ± 800 kilometers
Temperature of surface: 52 to 63 kelvins

vapor would carry away heat; when the vapor condensed, it would release that heat. "As long as the atmosphere is thick enough to flow around the planet," said Trafton, "the dark pole will be the same temperature as the pole in constant sunlight. There would be no variation in the temperature of the planet."

No one knows whether Triton has bare patches, polar caps, or an ice-free equator. "We really need to see the extent of the polar caps to pin down accurate models," said Trafton. "Voyager will tell us the radius, haziness, and the location and extent of surface ice. For modeling Triton's atmosphere these are the important quantities."

Voyager's Last Flyby

Voyager now flies toward an uncertain Triton. The 'real' Triton may be small or large, light or massive, bright or dark, snow-covered or bare. It may have an all-but-invisible wisp of methane or a dense veil of clouds. No one knows — but Voyager is coming.

"The first Triton observation in the near-encounter period will be a color picture," said Ellis Miner, assistant project scientist for Voyager. "It's our last opportunity to reliably capture a Triton larger than 3,600 kilometers in one image." Taking the picture and transmitting it to Earth will take 25 minutes. Voyager's infrared spectrometer will be looking at Triton simultaneously and measuring the temperature of Triton.

As Voyager speeds closer, the spacecraft will concentrate on Neptune's bizarre ring arcs and Neptune itself until a little less than three hours before closest approach. The cameras will then shoot an eight-frame color picture. Says Miner, "This is the last Triton observation before ring-plane crossing; we take this picture in case we encounter any hazards there."

Voyager speeds through the plane of Neptune's rings 56 minutes before closest approach to Neptune and then skims just over Neptune's north pole and on toward Triton. Then, two hours after closest approach to Neptune and three hours before closest approach to Triton, the robot spacecraft once again turns its cameras toward Triton.

"We'll be flying more or less over Triton's north pole," explains Miner, "which is dark at the time we fly by. As we pass Triton on a path that takes us well south of the ecliptic, we'll be looking back at the south pole of Triton. The best views of the south pole come after closest approach, but we'll get views of it on approach as well."

Voyager's cameras will first shutter eight frames that span the gibbous disk of the satellite and then six frames along the bright limb through different color filters, which is raw data for a color picture. Next Voyager shoots a mosaic of high-resolution black-and-white pictures, nodding the spacecraft to compensate for Triton's apparent motion.

"If we get images of the surface," said Cruikshank, "we'll see how fresh the surface is and whether any craters are left or whether they've been completely snowed in, melted, or whatever. Maybe in the extreme case we'll even see a glint of reflected Sun from a nitrogen sea."

An hour before closest approach, Voyager points its infrared spectrometer just off the bright limb of Triton and records the glow of Triton's atmosphere against the blackness of space in infrared radiation. "This 20-minute observation," said Miner, "will show us different species of molecules than we've detected by looking at the spectrum against the disk of Triton."

In the final minutes before closest Triton approach, Voyager will take its twelve highest-resolution frames and store them on the spacecraft tape recorder. Where the camera is pointed for these frames depends on how clear the atmosphere is. This will be determined five days earlier based on low-resolution frames. Haziness means shooting a sequence showing Triton from limb to terminator, while a clear atmosphere means shooting all images along the terminator.

Observations now come hot and heavy. Voyager's photopolarimeter and ultraviolet spectrometer instruments follow the star Beta Canis Majoris as Triton passes in front of it. How the star's brightness drops as the starlight passes through Triton's atmosphere can tell scientists how much aerosol haze and what gases make up the atmosphere. Then Voyager will pass through the shadow of Triton and out of sight of Earth and into darkness for roughly four minutes. As sunlight and radio beams are cut by Triton's limb, Voyager's instruments will take data that will yield Triton's diameter and the electrical properties and composition of its atmosphere.

"Up to two weeks before encounter we don't even know how big Triton is," Miner emphasized. "We're going to learn a lot."

"Voyager will give us only a 'snapshot' of Triton," said Cruikshank, "one view of Triton at a moment in time. We're convinced Triton is a dynamic object; we may have seen changes already in the ground-based data. What we learn from this encounter will help us interpret what's going on with Triton for decades to come."

Come next August 25, will the real Triton please stand up? □

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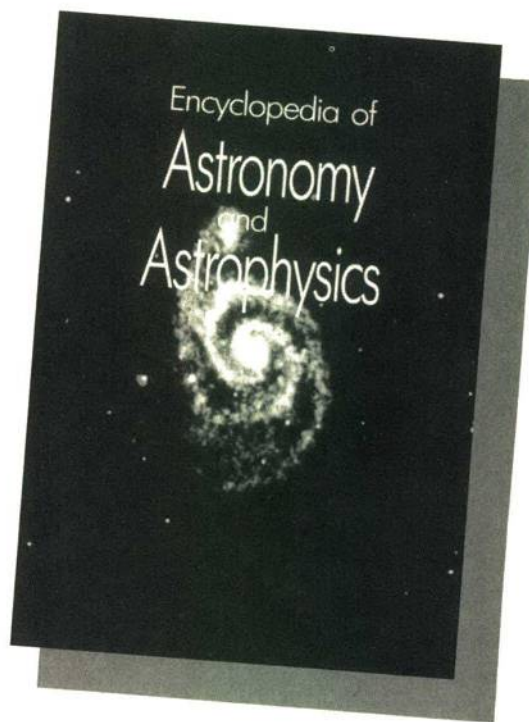
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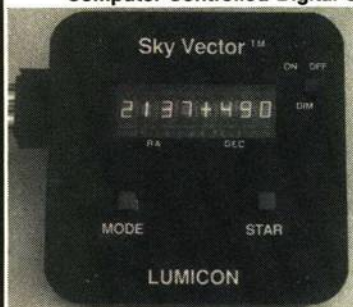
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Barnard's 'Dark' Dilemma

Were E. E. Barnard's newly discovered dark nebulae "holes in the heavens" or regions obscured by interstellar dust?

by Gerrit L. Verschuur

For well over a century astronomers believed holes in the heavens existed between the stars. These holes were thought to be empty, starless regions in interstellar space that in telescopes appeared as voids in the rich starry background of the Milky Way.

Today astronomers recognize that these holes and rifts in the Milky Way are dense regions of dust that block the starlight behind them. But before the 1930s the nature of these objects and of their relation to interstellar matter was not clear. Although as early as the 1850s a handful of astronomers suspected that dark, obscuring masses must exist, many astronomers assumed that the holes in space were regions sapped of interstellar matter in the making of stars. The nebulae and dust that could be seen were thought to be isolated phenomena.

One of the first individuals to systematically study these "vacancies" in space was Edward Emerson Barnard. Ironically, Barnard never fully accepted the idea that these dark regions were obscuring dust clouds; he was inclined to believe they really were holes in the heavens. Nevertheless, the photographs and catalogs he made of these objects between the late 1800s and early 1900s propelled the study of interstellar matter into the twentieth century.

Barnard was born on December 10, 1857, in Nashville, Tennessee. His father died before Edward was born and his mother had an arduous struggle to support herself and her two sons. When Barnard was three years old, the Civil War broke out, and two years later Nashville became an important city in the war, an event that was to provide for the survival of the Barnard family in a most unusual manner. The Cumberland River that flowed through town was always filled with debris including containers of hardtack (dried biscuits). Edward helped keep his family alive during the war by retrieving the flotsam.

Despite the fact that he had only two months of formal schooling, Barnard rose to accomplishments that even the most educated seldom achieve. He traveled a long way in body and spirit from a childhood of pov-



THE JUPITER CAMERA on the roof of Van Stavoren's Nashville studio, 1866.

erty and war to use the greatest telescopes at the foremost observatories in the world.

Barnard Discovers Astronomy

From Barnard's ninth year he worked to support the family. According to Barnard biographer Edwin B. Frost, "His mother was a woman of character, and did not lose her taste for culture in the struggle with poverty. The name, Emerson, given to the young son in honor of our American philosopher, was evidence of this. His mother had a taste for art, also, and partially supported herself by modeling wax flowers. That she had impressed on her son character and self-reliance was indicated by her statement that the lad, when less than nine-years-

old, could be depended upon to do a task in which many other boys had failed."

Frost was referring to Barnard's job as a human clock drive in a ponderous enlarging camera mounted on the roof of Van Stavoren's Photographic Gallery in Nashville. The camera, known as "Jupiter," had to stay pointed at the Sun so the intense light could be used to photographically make enlargements from negatives. A man sat inside the device while an assistant turned the wheels by hand to track the Sun. The time exposures were considerable. Sometimes Van Stavoren painted from the image and had to have it fixed in position for an hour or more.

Other boys had gone to sleep at the task, but Barnard succeeded. He worked at the studio in various capacities for seventeen years and during that time he developed tremendous patience and concentration. Thus, at the age of nine, his training to become the world's greatest celestial photographer began. No one, least of all Barnard himself, could have imagined where his destiny lay.

In 1870 J. W. Braid from New York City was employed as an operator at the Photographic Gallery.

EDWARD EMERSON BARNARD stands beside the Bruce Telescope at Yerkes Observatory in 1922. Barnard used this telescope to photograph dark nebulae.



Barnard, who was now thirteen, still patiently filled the role of human guide motor, but he had also become enamored of the night sky.

"I can recall when I was a small child," Barnard wrote in the *Christian Advocate* in 1907, "lying out in the open air in an old wagon bed, flat upon my back on pleasant summer nights, watching the stars. I soon knew the stars thoroughly as the seasons came and went." He did not know the names of the stars or constellations because there was no one to teach him, yet he came to treat the stars as friends who would return to visit every year. "I soon saw that a few of them changed their places among the others, but I did not know that they were planets."

During the long hours on his job he had become interested in the properties of lenses and told Braid he

wished he could get some lenses and fix them up to look at the Moon and planets. Braid was soon able to help this unusually observant boy in a fortuitous manner. "One day when I was in the shop of Mr. Charles Schott I noticed an old ship's spyglass hanging on the wall," Braid reported. "It had no lenses. He had bought it for old brass, and intended to cut it up. I made an offer to buy it, and when I told him I wanted it for Ed Barnard he let me have it for two dollars."

In due course he and Barnard ordered a 2-1/4-inch objective lens of 32-inch focal length from McQueen and Company of Philadelphia. "We made an eyepiece out of the wreck of an old microscope, which gave a power of about 38," said Braid. "A simple alt-azimuth mounting was made. Barnard already had a good tripod which had been a surveyor's instrument stand."

The scene was set. The teenager and his mentor went out into the night and Barnard turned the telescope on the planet Venus, which showed a beautiful crescent. "He was delighted," Braid said. Barnard then viewed the Moon, Jupiter, its four moons, and several sets of double stars, such as Mizar in Ursa Major. "The simple telescope gave Barnard more pleasure than anything else in his whole life," wrote Braid. The feeling Barnard had upon looking through his telescope that night determined his life's work. Every clear night for the rest of his life he pursued the joy of that first occasion by looking at the heavens through a telescope to see new wonders.

"It is impossible to look at the original negatives of these objects and not be convinced that there is something dark between us and the stars."
— Heber J. Curtis



THE "WILLARD" PORTRAIT LENS, here mounted atop a 6-inch refractor, was used by Barnard to photograph large areas of the Milky Way such as northern Sagittarius (right).



In 1871 Van Stavoren's business failed and his property was sold to pay off the bank. The studio and its photographic equipment were sold to Rodney Poole, who kept the employees and continued the business. The great "Jupiter" camera was dismantled and Barnard moved his telescope onto the vacant platform on the roof, which he used as his observatory. By then Barnard had built a larger 3-inch telescope, which apparently did not function as well as the original 2-1/4-inch objective lens. Nevertheless, he entertained friends and visitors up there with views of the heavenly bodies.

Although he regularly watched the heavens from the roof of the photographic gallery, Barnard still knew nothing about astronomy. He recognized patterns of stars but knew none of their names or those of the constellations. In Nashville there was no one to teach him. What little education he had received was provided by his mother, and that did not include astronomy. Although he wanted to learn about astronomy, there weren't any books to turn to for information. But then fate intervened.

One day a young man Barnard had befriended and had on occasion lent money — a born thief constantly in trouble with the law, it turned out — showed up on his doorstep.

"On this night," Barnard reported, "I was in no mood to be gracious for he had come to borrow money from me which I knew from experience would never

come back. As security for the return of the money he had brought a large book. This I refused to look at." Finally, to get rid of him, Barnard gave the man the two dollars he wanted to borrow.

After the thief left, Barnard, much to his delight, discovered the book was about astronomy. It had an enchanting title: *The Sidereal Heavens and other subjects connected with astronomy, as illustrative of the character of the deity, and of an infinity of worlds.* (Self-explanatory titles were in vogue.) Published in 1840, the book was written by Thomas Dick, a Scottish philosopher and "divine" who also wrote *The Christian Philosopher*.

Excitedly Edward skimmed the book, which included star charts that gave the names of the stars with which he was already so familiar. "It was but a few minutes until I was comparing these with the sky from my open window, and in less than an hour had learned the names of my old friends. . . .

"It is to be hoped that my sins may be forgiven me for never having sought out the rightful owner of that book in all these long years," he later wrote.

Dark Regions among the Stars

Barnard rapidly absorbed the words of the Scottish cleric, words that were to influence the rest of his life. Thomas Dick wrote about the first telescopic observation of the Orion Nebula, which dated back to 1656 when the Dutch physicist and astronomer Christiaan Huygens drew attention to "one phenomenon among fixed stars worthy of mention," which, as far as Huygens' knowledge went, had "hitherto been noticed by no one."

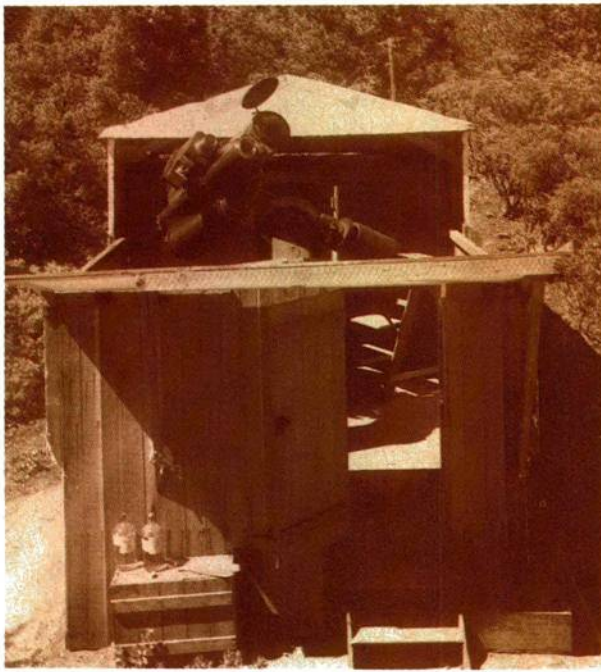
Dick described dark regions amongst the stars and drew upon the words of William Herschel when he wrote that "in certain directions the spaces . . . were generally deprived of their stars, so as often to afford many fields without a single star in it." These, Herschel had thought, were "great cavities or vacancies [formed] by the retreat of the stars towards the various centers which attract them." The Reverend Dick drew liberally from Herschel's monumental work entitled "The Construction of the Heavens," in which Herschel described how he believed the luminous regions (e.g. the Orion Nebula) and the dark regions fit into an overall picture.

"It is an opinion now very generally entertained," wrote Dick, "that the self-luminous matter to which we refer is the chaotic materials out of which new suns or worlds may be formed. Nor do we conceive that this hypothesis is inconsistent with what we know of the attributes and operations of the Almighty." The extraordinary fact is that many of the self-luminous nebulae are indeed regions of star formation, as modern research has revealed.

Dick, in his attempts to popularize astronomy within the context of the religious tenor of his times, threaded a delicate path through the realm of fact and hypothesis so as not to offend believers. He reported that Herschel thought the nebulosity might develop and change into stars, that the stars develop into dense clusters that would, in turn, attract more matter (stars) to them. Thus, according to Herschel, voids or "holes in the heavens" would be formed. These regions were drained empty of stars by the gravitational attraction of large concentrations of matter — the visible nebulae.

Barnard was to carry Herschel's image of the holes in the heavens with him for the rest of his life.





BARNARD PHOTOGRAPHED the southern realm of the Milky Way with the Bruce Telescope at Mount Wilson in 1905.

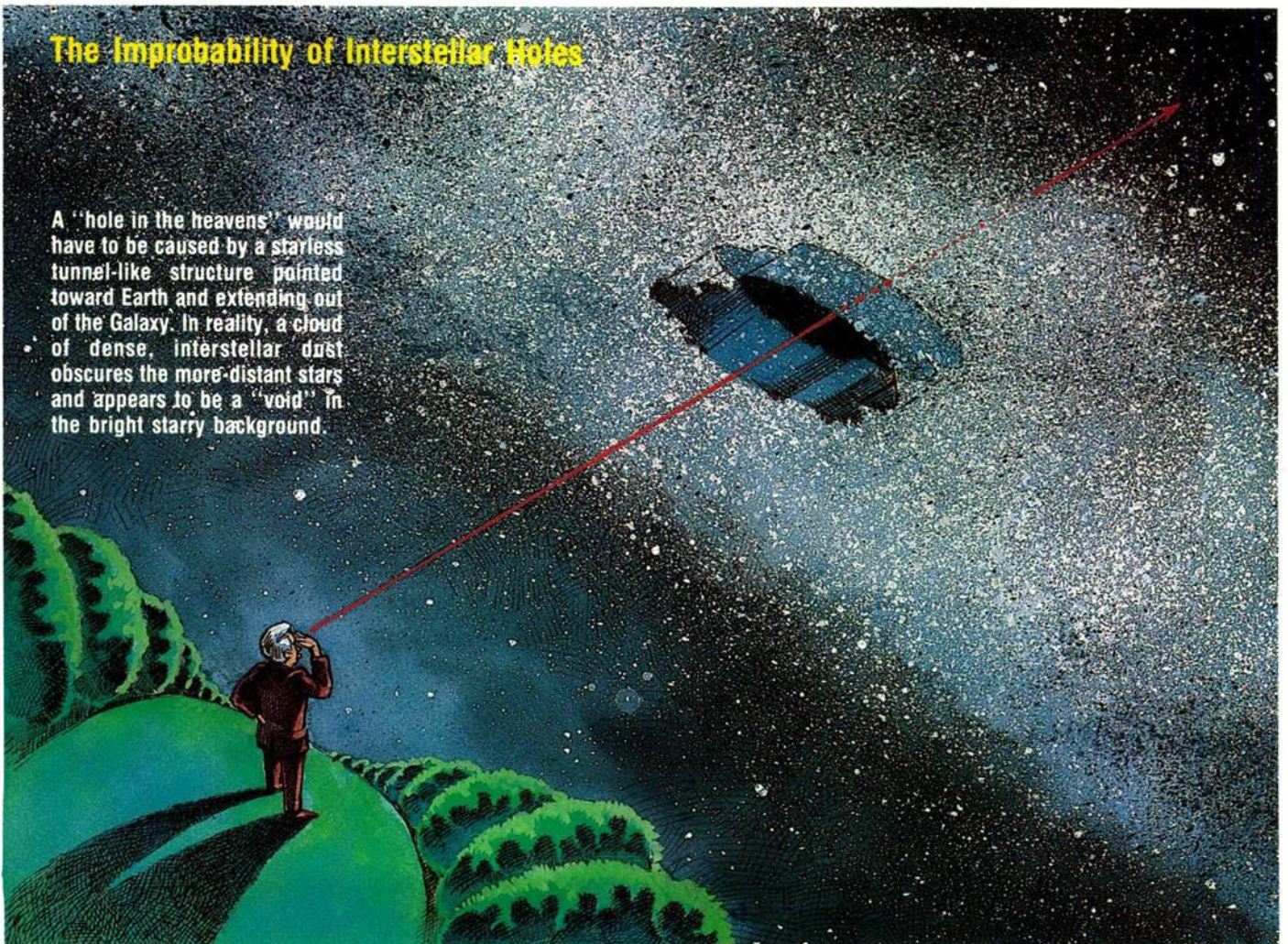
But what about Herschel? Why did he think there were holes in the heavens? It turns out that he had bought his first book on astronomy when he was thirty-five years old, a book written by the amateur astronomer James Ferguson in 1778. It bore the title *Astronomy explained upon Sir Isaac Newton's principles, and made easy to those who have not studied mathematics*.

While most astronomy books of the time addressed only the solar system, Ferguson considered the entire starry realm and his universe a three-dimensional wonder. Ferguson dwelt upon descriptions of the bright nebulae, which he called "lucid spots" or "cloudy stars." The Orion Nebula was "the most remarkable of all the cloudy stars," he wrote. "It looks like a *gap in the sky*, through which one might see (as it were) part of a much brighter region. Although most of these spaces [referring to the nebulae] are but a few minutes of a degree in breadth, yet, since they are among the fixed stars, they must be spaces larger than what is occupied by our solar system." (Italics added.)

This notion of gaps or spaces between stars might have made an impression on Herschel, who later extended the concept. Then Thomas Dick wrote about it, so that, in turn, a young and impressionable Barnard in Nashville, aching to learn about the heavens, would find the description in a stolen astronomy book. Such are the connections that determine our lives.

The Improbability of Interstellar Notes

A "hole in the heavens" would have to be caused by a starless tunnel-like structure pointed toward Earth and extending out of the Galaxy. In reality, a cloud of dense, interstellar dust obscures the more-distant stars and appears to be a "void" in the bright starry background.



Holes or Interstellar Matter?

The thrill of reading Dick's book made Barnard desire a larger telescope. In due course he obtained a 5-inch telescope and began his self-taught study of comets, notching one or two discoveries per year before he quit in the summer of 1877 to teach himself the mathematics he had missed in school. Barnard's comet discoveries made him a celebrity in Nashville, and his admirers responded by raising enough money to offer him a combined fellowship and instructorship at Vanderbilt University in Nashville. This position eventually gave him the background he needed to be able to accept positions at Lick Observatory in 1887 and then at Yerkes Observatory in 1897.

Once he was settled at Lick Observatory — which was beginning its first year of operation — Barnard proved himself a tireless observer. In his first year he made detailed drawings of Jupiter and discovered four comets. He also began photographing what he considered his most difficult subject: the Milky Way. To make these photographs, Barnard used a 6-inch camera lens known as the "Willard lens," named for the New York company that manufactured it. The lens had been used by a San Francisco photographer to make portraits. Most portrait lenses at the time had large apertures and wide fields, which enabled a lot of light to be gathered and thus shortened the "sitting" time during exposures. This

**Dark regions in the stars are
"great cavities or vacancies
[formed] by the retreat of the
stars towards the various centers
which attract them."**

— William Herschel

made them ideal for wide-field sky photography.

However, exposure times for the Milky Way were still quite long; Barnard's exposures typically ran several hours. Nevertheless, his persistence paid off: he found the "holes in the heavens" Herschel had described. Barnard published his first images of the dark regions in *Knowledge*, a popular science magazine, in 1894.

The editor of *Knowledge* was A. C. Ranyard, astronomer and secretary of the Royal Astronomical Society in England. Following Barnard's brief description of one of the photographs, Ranyard published an editorial comment that Barnard essentially ignored until much later in life.

Barnard provided a description of the image of the Milky Way around the star Theta Ophiuchi, which showed many dark regions. "It will be noticed that in many of these vacancies there are 'deeper depths' yet, which almost suggest that the appearance of the diffused nebulosity over the regions is real nebulosity, and that these dark and black patches in it are thin places and actual holes."

Ranyard, however, could not accept this interpretation. "The dark vacant spaces referred to by Professor Barnard," he wrote, "seem to me to be undoubtedly

dark structures, or absorbing masses in space, which cut out light from a nebulous or stellar region beyond them."

Ranyard did more than editorialize. He considered the geometry involved and pointed out that it is easy to imagine a narrow stream of dark nebulosity cutting out light and seen projected on the sky. But he found it hard to believe the holes pointed away from Earth in a specific direction and appeared vacant. "The probabilities against such a radial arrangement with respect to the Earth's place in space seems to my mind to conclusively prove that the narrow dark spaces are due to streams of absorbing matter, rather than to holes or thin regions in bright nebulosity," Ranyard wrote.

Though Barnard certainly read Ranyard's comments, all Barnard said about them at the time was that the photograph had been "accompanied by an article by the editor on the singular features shown in the photograph."

Perhaps letting his upbringing and education get the better of him, Barnard may have felt that the final interpretation of these dark regions — as being caused by either holes or obscuring matter — should be left to more learned colleagues. Over the next twenty-nine years Barnard reflected over the dilemma, vacillating between models. Some of this ambivalence is evident in the many papers and articles he published on the subject. At times he treated these starless regions of the Milky Way as "dark markings," at other times as "vacant" regions of the sky.

In 1905 while at Yerkes Observatory he wrote: "For many years I have called attention to the fact that many of the nebulae occupy vacant regions as if their existence was in some way the cause of the scarcity of stars. In reference to these dark lanes and holes, there seems to be a growing tendency to consider them dark masses nearer us than the Milky Way and the nebulae that intercept light from these objects."

Perhaps the dark markings were dead nebulae, he wondered, in a 1907 paper. "The idea of the absorption of the light of the stars by a dead nebula or other absorbing matter has been used by some astronomers as an explanation of the dark or starless regions of the sky. Though this has not in general appealed to me as a true explanation — an apparently simpler one being that there are no stars in these places — there is yet considerable evidence to commend it in some of the photographs."

Some of the dark regions, such as the one in Ophiuchus, were so "empty" that astronomers could see no stars in them at all.

"There exist dark lanes," Barnard wrote in 1910, "which are so devoid of stars and nebulosity of any sort that an incident which befell Professor Tucker is worth recalling." Richard H. Tucker, who worked at Lick Observatory in the late 1800s, had the misfortune of pointing his telescope, unknowingly, at such an object. He had fixed his telescope and was watching the stars drift by. Barnard goes on: "One night he had set his telescope in the region a little north of Antares. . . . Presently no stars came into the field of his telescope. After watching for some time he finally concluded the sky had clouded over, but on looking out he found it perfectly clear. His telescope had been pointed to this lane and nothing but blank sky had passed."

The dark lanes there happen to run east to west, so

Dark Realms of the Milky Way



Barnard's long-exposure photographs of the Milky Way revealed numerous dark "holes" and lanes that the telescope alone could not detect. This montage, constructed from photographs in Barnard's *Atlas of Selected Regions of the Milky Way* (published by the Carnegie Institution in 1927), shows many of these features.

One of the first photos Barnard published was of the region around Theta Ophiuchi (frame A), which contains one of the largest dark nebulae in this part of the sky (bottom of frame). An irregular rift runs west (to the right) out of this dark area nearly to the edge of the frame. Bar-



B



C



D

nard called the westernmost extension of this rift the "sink hole, because of its form and the structures in it." At upper center in this frame is the "Snake Nebula," which Barnard called "as strange an object as can be found anywhere in the sky."

One of the most prominent dust lanes visible from Earth begins at 22 Scorpii (the eyelike star in frame C) and extends eastward for about 12 degrees, crossing the Milky Way into extreme southern Ophiuchus (frames A and B). The edges of this lane are especially sharp in Scorpius. Another less-defined lane lies to its north (frame B).

Other objects in these photos include Antares (frame C, below the "eye" star), the globular cluster M4 (to the right of Antares), globular cluster M19 (upper bright object, frame D), M62 (lower bright object, frame D), and Theta Ophiuchi (frame A, below center).

Tucker's telescope had faithfully scanned along the empty lane, a dramatic illustration of just how dark these lanes can be.

Barnard came close to inferring the truth atop Mount Wilson in 1905 when he photographed southern objects with the 10-inch Bruce photographic telescope. He had been standing outside, looking up at the bright glow of the Milky Way, and had seen something remarkable.

"I was struck by the presence of a group of tiny cumulus clouds scattered over the rich star-clouds of Sagittarius. They were remarkable for their smallness and definite outlines — some being not larger than the moon. Against the bright background they appeared as conspicuous and black as drops of ink. They were in every way like the black spots shown in photographs of the Milky Way, some of which I was at the moment photographing."



BARNARD SPENT HIS LATER YEARS at Yerkes Observatory recording and mapping the dark nebulae he discovered.

He made the connection because terrestrial clouds had obscured the view of the Milky Way. In those days when the cities near major observatories were still quite small and not spangled with lights, the clouds would have been totally dark.

"The phenomenon was impressive and full of suggestion," he wrote. "One could not resist the impression that many of the black spots in the Milky Way are due to a cause similar to that of the small black (cumulus) clouds mentioned above — that is, more or less opaque masses between us and the Milky Way."

Yet even this insight did not push him to taking a side once and for all.

Never Fully Convinced

In 1918 Lick astronomer Heber J. Curtis, champion of the "island universe" theory of galaxies, drew the same conclusion that Ranyard had outlined twenty-four years before. Curtis was unaware of Ranyard's editorial when he wrote on the dark markings seen projected against the bright Lagoon Nebula M8: "I have never been able to believe that these are really 'holes' in the nebula." It was much more reasonable, thought Curtis, to suppose they were masses of dark matter. Holes had to be shaped like tunnels all pointing away from our position in space, which was "against all probability."

"It is impossible to look at the original negatives of these interesting objects and not be convinced that there is something dark between us and the general background of stars," Curtis wrote. "I firmly believe that these are actual 'dark nebulae.'" Curtis also pointed out that the random motions of stars should in any case be expected to fill such holes or at least blur their edges.

But Curtis' belief was not enough to convince Barnard, and the empirical efforts of other astronomers came too late. In 1923, the year of Barnard's death, the German astronomer Max Wolf demonstrated that starlight radiating from these dark regions was weakened as if by some inhibiting material. And in 1930 the issue was finally put to rest when the Swiss-American astronomer Robert Trumpler showed that the light from globular clusters was dimmed by interstellar matter.

However, the first to give the correct explanation for the dark markings wasn't Curtis, Wolf, or Ranyard. That credit goes to an Italian astronomer who had given the correct explanation in the mid-nineteenth century.

Father Angelo Secchi announced in 1853 that "in these studies [of nebulae] one interesting fact stands out; namely the probable existence of dark masses scattered in space. These dark masses were seen because of the light background on which they are projected. Up to now these masses have been classified as 'dark holes.' This interpretation [of dark holes] is however very improbable, particularly after the discovery of the gaseous nature of the nebular masses. It is more likely that the darkness is the result of a dark nebulosity, which seen against a lighter background, absorbs the light."

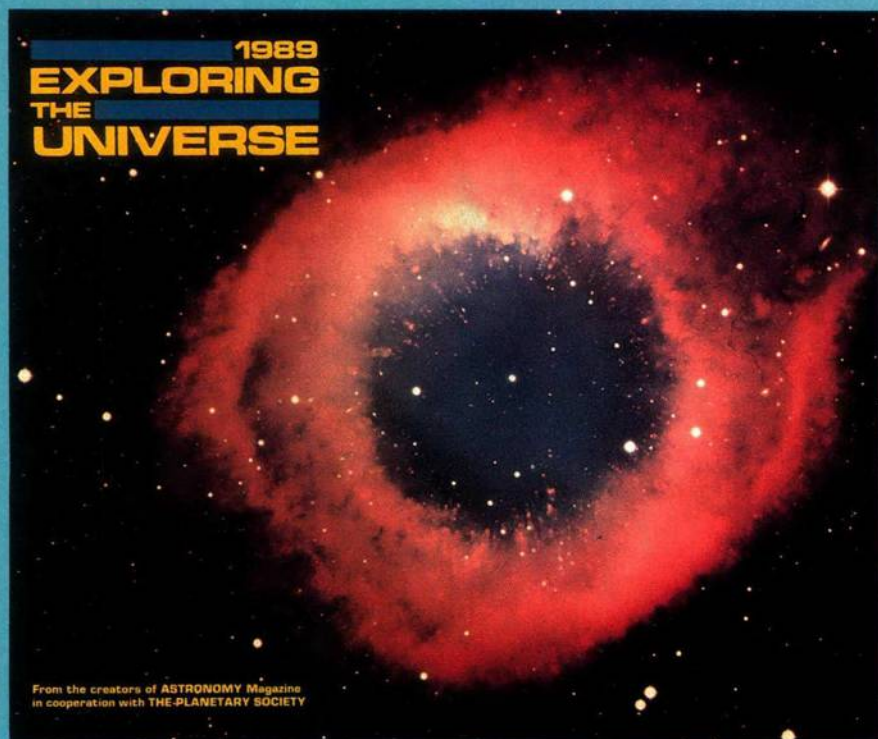
In 1919 in his last paper on the subject Edward Barnard seemed to concede that dark matter must exist between the stars. "I did not at first believe in these dark obscuring masses," he wrote. "The proof was not conclusive. The increase in evidence, however, from my own photographs convinced [me] later, especially after investigating some of them visually, that *many of these markings* were not simply due to an actual want of stars, but were really obscuring bodies nearer to us than the distant stars." (*Italics added.*)

But then, as if to cover all bases, Barnard claimed that according to William Herschel's son, John — who had surveyed the southern sky from Cape Colony, South Africa, in the early 1800s — there existed "real vacancies amongst the stars" in the southern skies.

Barnard died February 6, 1923. To the end of his life he left himself an opening, as it were, and never stated with total assurance that the idea he had garnered from Thomas Dick's book — that there were holes in the heavens — was completely without substance. Though most astronomers who studied Barnard's photos eventually accepted that interstellar matter blotted out the light of the background stars, Barnard, for whatever reason, could not embrace such a notion. His work nonetheless underscored the importance of understanding the regions between the stars, a realm astronomers are still wrestling with today. □

*Gerrit L. Verschuur is a freelance science writer and researcher who lives in Bowie, Maryland. He is the author of *Interstellar Matters*, recently published by Springer-Verlag. Verschuur's most recent article, "On the Trail of Exotic Pulsars," appeared in the December 1988 issue.*

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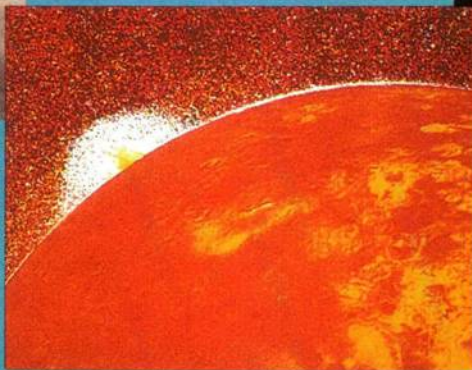
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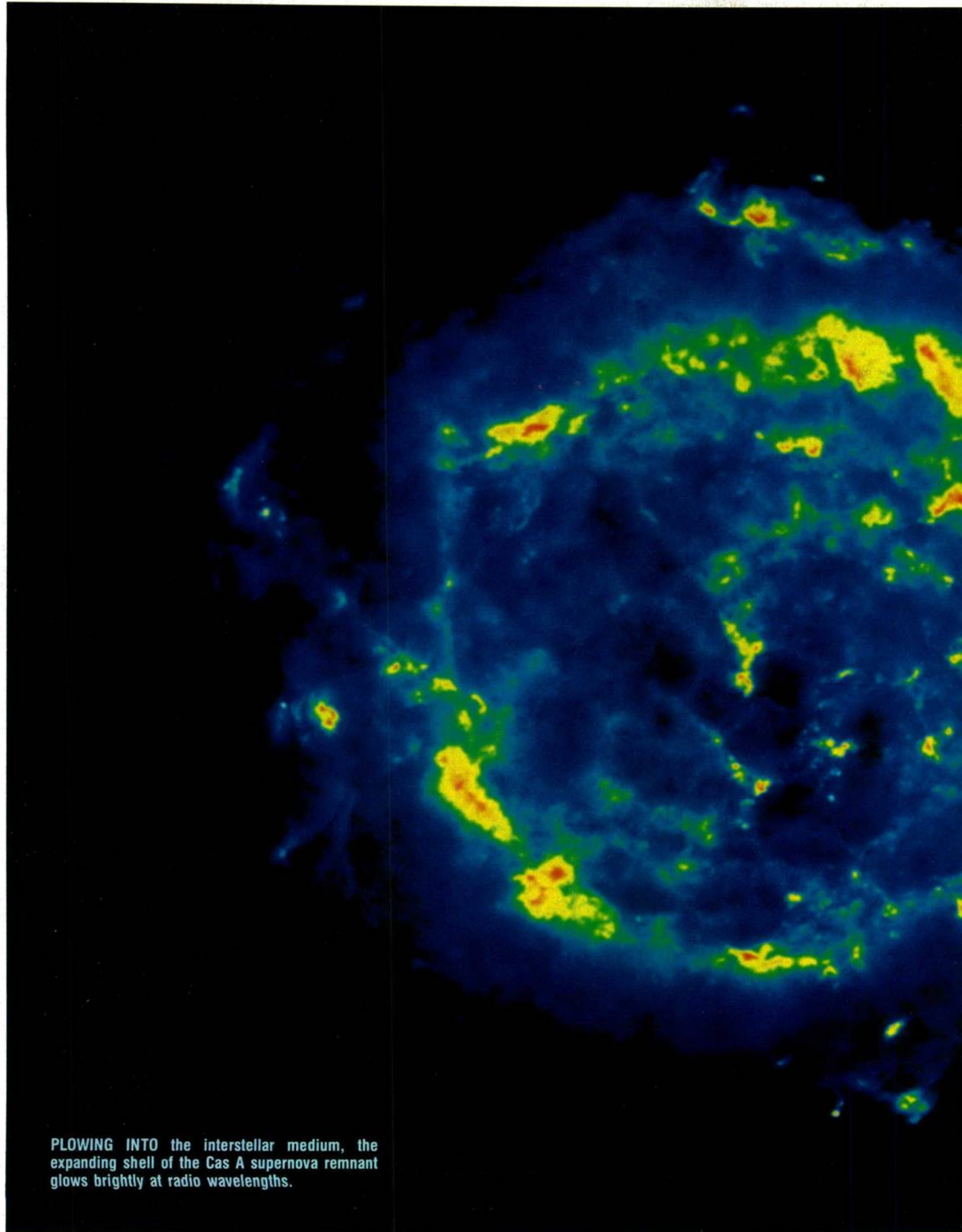
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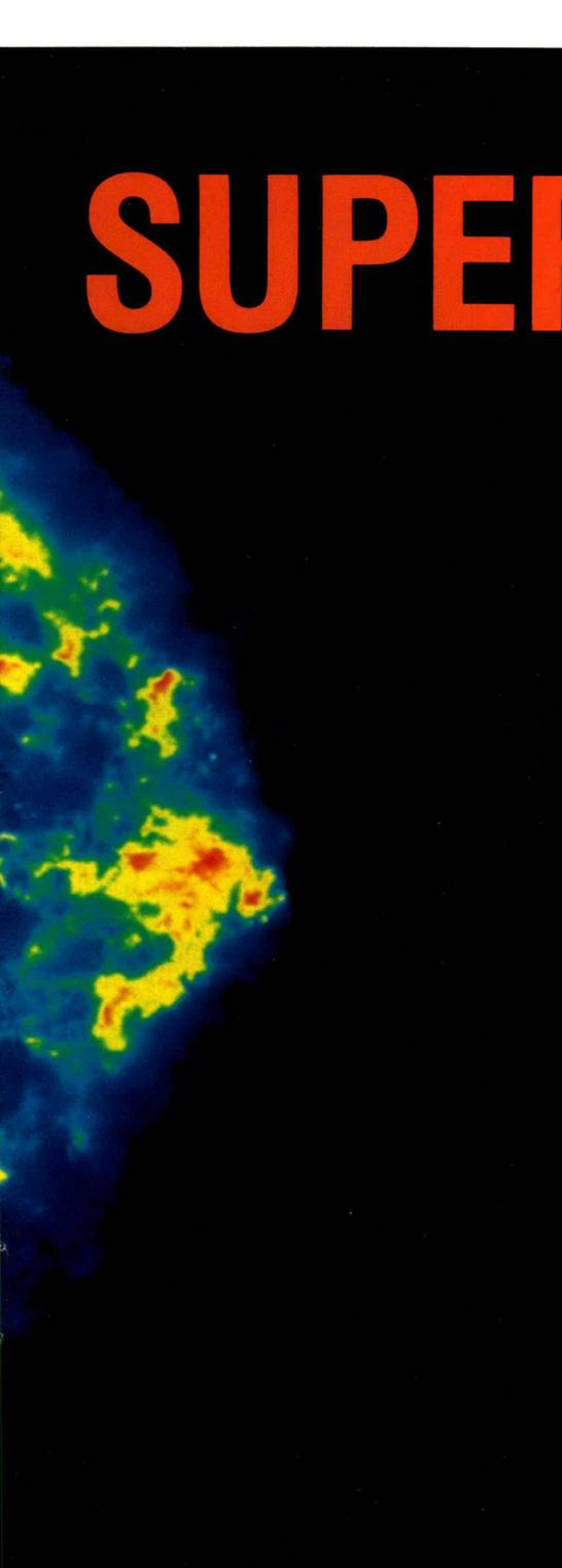
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PLOWING INTO the interstellar medium, the expanding shell of the Cas A supernova remnant glows brightly at radio wavelengths.

SUPERNOVA AFTERMATH

The Cassiopeia A gas shell,
thrown off by the explosion of
a dying star centuries ago,
continues a life of its own.
by Laurence A. Marschall



Three centuries ago an inconspicuous star in the constellation Cassiopeia blew up. Today we see the scattered and fading remains of that explosion as a powerful radio source called Cas A.

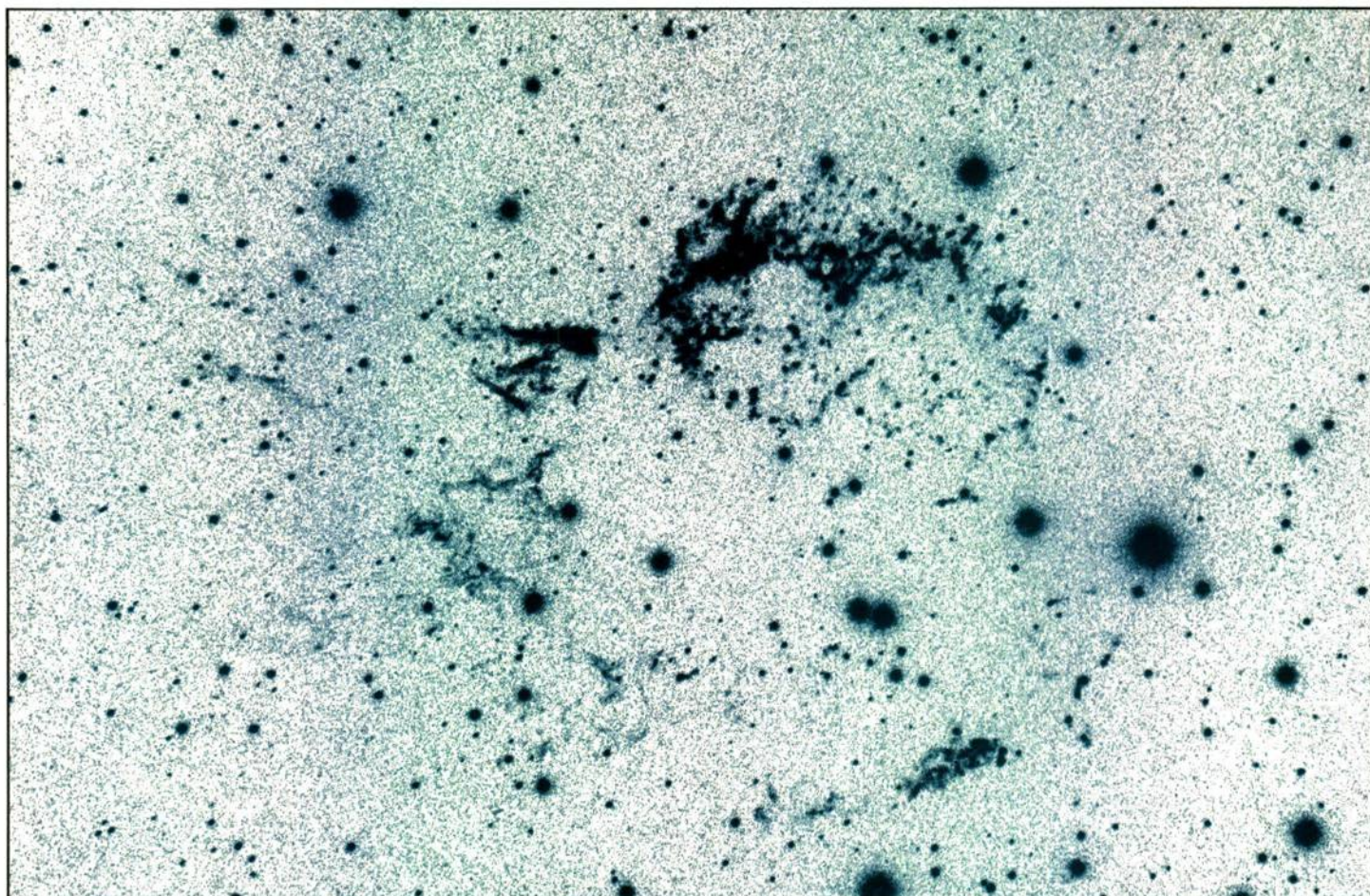
The high-resolution radio image of Cas A shows what happens when the shredded debris of an exploding star, or supernova, encounters material in the surrounding space. The roughly spherical shell of the supernova remnant marks the ongoing collision between gaseous material ejected from the outer layers of the star and the tenuous interstellar gas. The symmetry of this expanding shell — now some 12 light-years in diameter — is broken by voids and wispy extensions. These are areas where more rapidly moving material from deeper layers of the exploding star is catching up to and punching through the material in the outer expanding shell.

The radio waves arise from electrons that are liberated from atoms in the shock of the supernova explosion. These electrons, traveling at speeds close to the speed of light, emit radio radiation as they are buffeted by magnetic fields within the remnant.

Cas A was discovered in 1942 by engineer and ham-radio operator Grote Reber, who made the first radio map of the sky. Reber's crude map showed three distinct radio sources besides the Sun. The brightest of these was in Cassiopeia, and astronomers later named the source Cassiopeia A, or Cas A for short.

Nowadays astronomers can obtain detailed radio images undreamed of in the 1940s. The radio image of Cas A was produced from data acquired by the Very Large Array (VLA) radio telescope in New Mexico. The twenty-seven radio dishes that make up the VLA give astronomers the ability to examine the structure of radio

Adapted from The Supernova Story by Laurence A. Marschall (Plenum Press, 1988).



The Facts on Cas A

Distance:	9,500 light-years
Diameter:	12 light-years
Age:	About 300 years
Discoverer:	Grote Reber in 1942
Progenitor:	Nitrogen-rich Wolf-Rayet star
Supernova type:	Probably Ib
Fastest-moving gas:	About 10,000 km/sec

sources like Cas A in exquisite detail. The raw data from the radio telescope were then fed into a Cray supercomputer, which produced the image shown here. The strongest radio radiation is colored red, followed by yellow, green, and blue, in descending order of strength.

Such high-resolution radio images reveal the outward motion of the gas that makes up the supernova remnant. Optical images also reveal these changes in structure, although a smaller fraction of the gas is visible on these images (above). Over time the moving shreds of gas change position slightly, revealing the remnant's expansion. By measuring the expansion rate, astronomers can calculate that the supernova explosion occurred within a few years of 1680.

Since that time the shreds of gas have been moving

HUNDREDS OF FAINT SHREDS of gas are the only evidence of the Cas A supernova remnant seen at optical wavelengths.

away from the site of the explosion. The expanding fragments are divided into two distinct types. Some of these knots of gas, containing large amounts of oxygen or nitrogen but very little hydrogen, move at speeds up to 8,500 kilometers per second. This gas obviously comes from the supernova explosion itself.

Other fragments of gas, rich in hydrogen and nitrogen, are not moving much at all. If the slow-moving fragments were expelled from the same star as the faster-moving gas, they must have started their journey tens of thousands of years earlier than the faster gas. Most likely they formed part of the outer layers of the aging star before it blew up. The material would have been shed in a "stellar wind," a process typical of the extremely massive stars that form supernova remnants like Cas A. Thus, the slow-moving gas is a relic of the late life of the star, while the fast-moving gas is a product of the star's violent death.

As the expanding debris from the explosion interacts with material in interstellar space, the expansion gradually slows. This, in turn, cools the gas. In the distant future — perhaps 30,000 to 50,000 years from now — the remnant will be 100 light-years across and beginning to blend with its surroundings. Only long wisps and thin sheets of gas will remain, drifting slowly away from the site of the ancient explosion. In a few million years Cas A will be indistinguishable from the interstellar material in that part of the Galaxy. □

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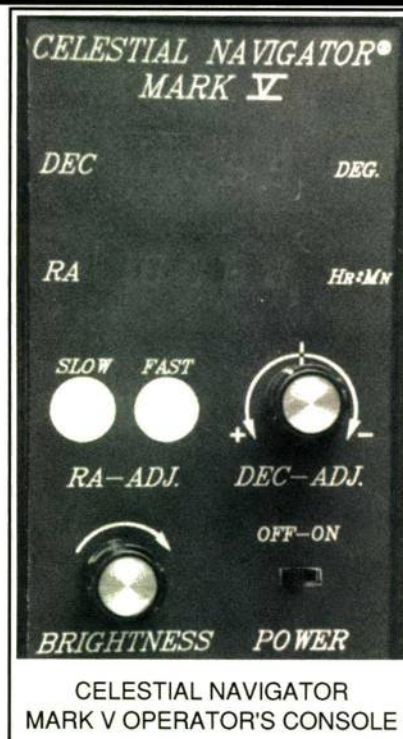
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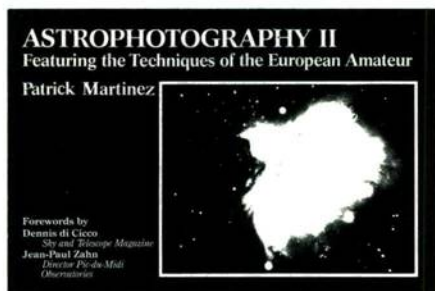
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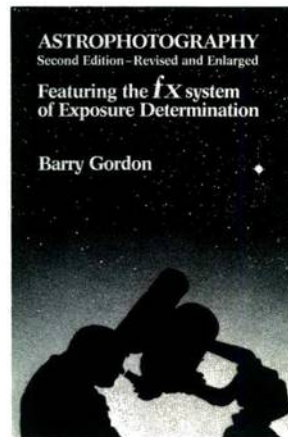
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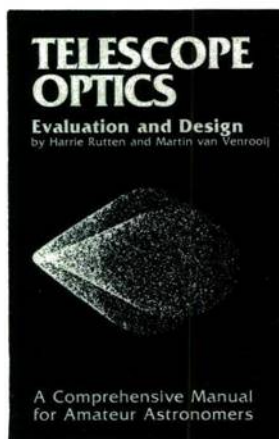
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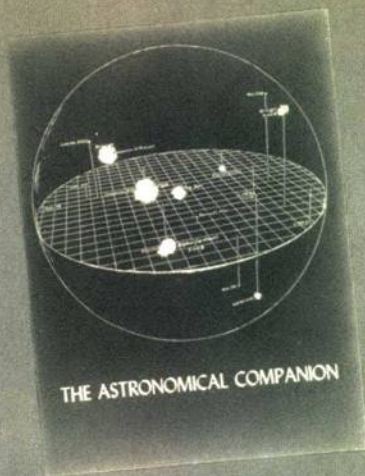
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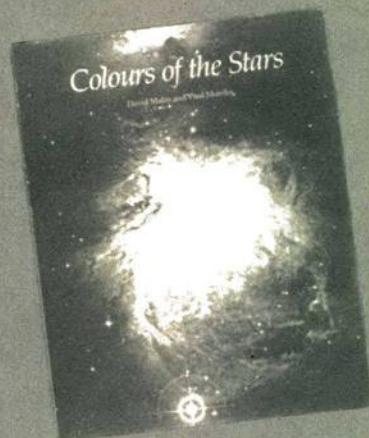
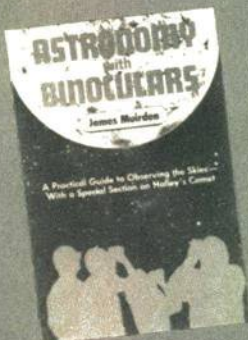
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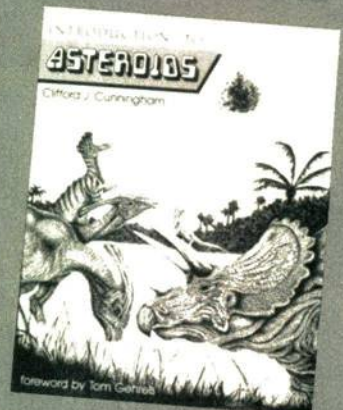
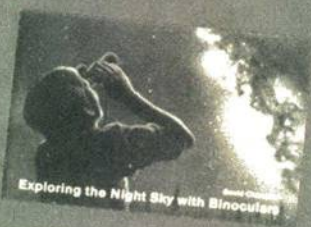
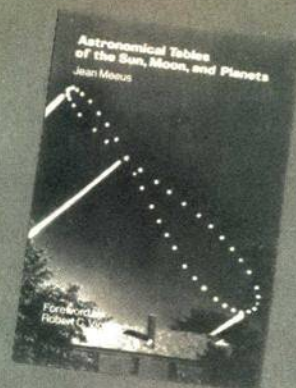
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An Uphill Battle for Comet Research

Helicopters make a mountain comet-observing site accessible even in winter when the only road is buried under snow.

by Ly Ann Shore

The sky overhead begins to flicker as the propeller gathers speed. At the "Water Canyon Heliport" at the foot of the Magdalena Mountains in the central New Mexico desert the helicopter sways slightly and then is airborne. Below, the bare plain opens up and spreads out; ahead, the ridge twists and climbs the snowy flanks to the mighty spine of the Magdalenas.

We follow the ridge as it climbs; the mountain road winds below us. At low elevations the road is clear of snow and ice, but higher up, especially on the heavily wooded north face of the mountain, enough snow and ice have been accumulating all winter to keep the road closed even to four-wheel drive vehicles. It may well be mid-April before the observatory truck will be able to make it all the way up the mountain again.

As we rise above the main ridge, the far side of the mountain drops off sharply. Beyond it sprawl the Plains of San Agustin, with the "Y" of the Very Large Array radio telescope in the center. We land smoothly on top of the mountain.

Our destination, the Joint Observatory for Cometary Research, lies atop the main ridge of the 11,000-foot mountain. Our mission is to fly the observatory crew and several hundred pounds of equipment and supplies up to the observatory for a two-week "dark run" of observations.

The Joint Observatory for Cometary Research (or JOCR, pronounced "joker"), an optical astronomical observatory operated by the New Mexico Institute of Mining and Technology and NASA, has been in existence for fifteen years. Its prime purpose is observing the large-scale structures in comets as a way of studying the solar wind. Whenever a bright comet appears, researchers make the trip up to the remote mountain site to observe it.

But until last year research was only conducted during warm weather months. During the winter, getting to this small, remote observing site poses quite a challenge. Snowstorms can close the observatory road and once a storm stranded an astronomer on the mountain for a week. But, because of the ideal observing conditions at JOCR, the observatory team has found solutions to the problems presented

by the severe winter weather. And, for the first time in 1987-88, research was conducted on the mountain throughout the winter.

Modern and Old-Fashioned

Observing at JOCR is a combination of "very modern and very old-fashioned astronomy," according to Daniel A. Klinglesmith III, a NASA scientist and JOCR program monitor. The observatory has a 14-inch Schmidt telescope, which is used to obtain photographic plates of comets, and a 16-inch f/35 Cassegrain telescope with a charge-coupled device, or CCD, system.

The CCD system is controlled by an IBM-AT computer. The 16-inch telescope is small by professional standards, but the CCD turns it into a sophisticated research instrument. The computer has a tape drive to transfer information to magnetic tape; an image display screen to examine, process, and analyze images on site; and a modem to transfer data over phone lines to other facilities. A spectrograph and additional imaging optics, currently being installed, will add spectroscopy to JOCR's arsenal of observational techniques.

Though the equipment is modern, the unheated observatory domes, where observers spend considerable time guiding and focusing the telescopes manually, offer old-fashioned observing conditions. The double-domed cinderblock observatory building is about 55 feet by 17 feet in size. It was winterized for the International Halley Watch in 1985-86 by New Mexico Tech astronomer Elliott P. Moore, who spent much of that relatively mild winter photographing Comet Halley with the JOCR Schmidt telescope. To minimize resistance to the fierce gusts of wind that often come from the west, the observatory's shed roof slopes to that direction.

The compact living quarters offer spartan accommodations for two



TO STUDY COMETS, astronomers brave winter at a remote site in the Magdalena Mountains.

DRY AND DARK, an 11,000-foot mountaintop is perfect for photography with a Schmidt telescope.





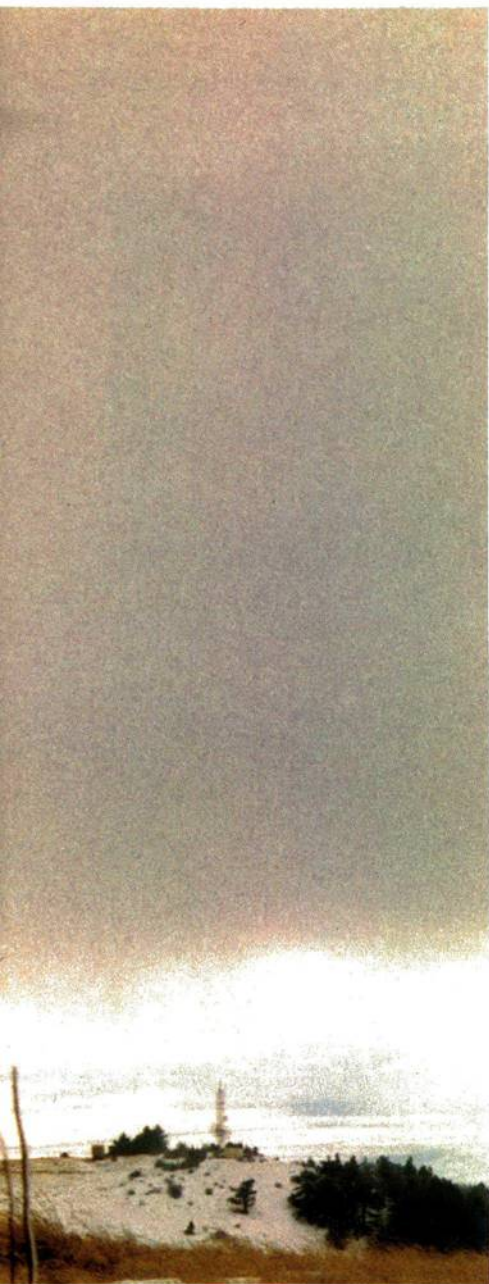
KEEPING THE OBSERVATORY ROAD OPEN with bulldozers proved too expensive and time-consuming, so now astronomers depend on helicopter airlifts to get to the Joint Observatory for Cometary Research in winter.

people or for as many as four with a little crowding. The 16-by-17-foot room holds a well-equipped kitchen, sofas for lounging and sleeping, and the computer system. A darkroom, bathroom, workshop, and storage areas are tucked between the living room and the south dome.

To keep snug in bad weather, the living quarters, sandwiched between the two domes, are windowless. A double set of doors opens to the east — an inner pair of glass doors for daytime lighting and an outer pair of heavy doors for insulation. These heavy doors also keep the living room dark during the day, so the astronomers can sleep until about noon after they've spent the night observing.

So Near and Yet So Far

As an astronomical site, the Magdalenas are remarkable both for an



altitude of 11,000 feet — 4,000 feet higher than Arizona's Kitt Peak Observatory — and the simultaneous nearness and remoteness of the site. Though JOCR is only about twenty-five miles by road from the town of Socorro, it is "4,000 vertical feet and twelve miles by road from the base of the mountain," Klinglesmith says.

As last winter's operations at JOCR began, the astronomers thought it would be possible to keep the road clear. But because of the remoteness of the observatory and the primitive mountain road to the site, keeping JOCR open last winter depended on airlifts.

"Winter operations are standard for large observatories," says Steven Shore, a New Mexico Tech astrophysicist, "but it's unusual to go through this kind of effort for this size facility.

What distinguishes JOCR is that it is a single-mission facility, not a large observatory with multiple telescopes."

However, JOCR's observing conditions more than justify the efforts to get to the site. The high, dry, dark location was ideal for testing the CCD system Klinglesmith had developed. JOCR also "wasn't being used to the fullest," according to Klinglesmith. "Last winter we had the capability to take advantage of this site and wanted to do so."

Most of last winter was spent calibrating JOCR's CCD system. "When you look at CCD images, you aren't looking at a photograph but rather directly at the data," says Shore. Displayed on a computer screen, the image — of a comet, planet, star, or galaxy — is composed of thousands of points of data representing measurements of light intensity. Calibrating the system allows observers to gauge the accuracy of observations — say, of a faint comet.

Calibration involves observations of known objects — standard stars and clusters — which are then compared to existing data for the same objects. The astronomers at JOCR took CCD images of galaxies to gain experience with faint, fuzzy objects like the comets they'll be using the system to observe. Calibration of a system produces no new science. "It's the essential step you always do *before* you can do original science with the system," says Shore.

While JOCR's location proved to be ideal for calibrating the CCD system, the remoteness of the site can cause potential problems for the astronomers while they're working at the observatory. Storms can move in suddenly, so it's important for the astronomers to be able to keep track of the weather. Thanks to the atmospheric physicists at New Mexico Tech, the observatory receives hourly weather updates and National Weather Service forecasts on the computer. This weather data can be used to make preliminary weather predictions.

"This fills in all the gaps in the television weather reports and is essential to winter operations," says Shore. "After all, you need to know if you're going to have to scam off the mountain."

Stranded on the Mountain

In December 1987, when the researchers were still getting to the observatory via the mountain road, a sudden, severe storm stranded Dan Klinglesmith at the observatory for a week. Rescuers couldn't even attempt to begin clearing the road until the blizzard had passed. A helicopter was on standby, but the weather was too

severe for it to land on the mountain.

After the blizzard ended, the rescue team was faced with the daunting job of bulldozing four feet of snow from more than ten miles of a rough road that twists up to the ridge through dense, snowy forest and across icy, wind-raked slopes.

While Klinglesmith awaited rescue, he had food, heat, electricity, and the spectacular view from the mountain that he shared with deer, coyote, and a bear or two. "Standing outside the observatory, I could see 120 miles in every direction except up," says Klinglesmith, "and looking up I could see for 2 million light-years."

Klinglesmith was able to contact the outer world via the phone lines while he was stranded. "As long as the telephones were operating, I had a link with the world," Klinglesmith recalls. "I could call a local telephone number in Socorro to connect with the computers at the Very Large Array, through which I could get on several computer networks. So, while stuck up there, I could still transfer information back and forth between JOCR, the VLA, and the NASA-Goddard Space Flight Center in Maryland."

After three days of back-wrenching work — work done at an altitude where even a short stroll can leave people breathless — the rescue crew reached Klinglesmith at the top of the mountain. This incident made it clear that the astronomers couldn't rely on the observatory road in winter. After the snowstorm it took three days to clear the road, only to have the next storm or blowing snow block the road again. The steep slope of the snow-packed road poses difficulties even for snowmobiles and SNO-cats. At this point the researchers decided that they would get to and from the mountain via helicopter.

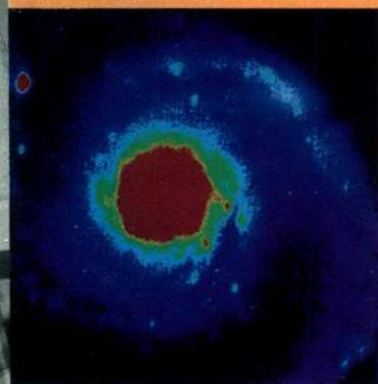
Rising above the Weather

Helicopter airlifts, even at about \$800 per trip, turned out to cost less than plowing the mountain road after every snowstorm. They were also faster and more convenient than hiking up the observatory road. Helicopters could also get heavy supplies up the mountain. However, although helicopters solved some of the transportation problems, they can only fly in daylight under good weather conditions.

After the decision to go with airlifts was made, there were still details about working on the mountain that needed to be worked out. "That first winter we were still learning what we were doing," says Klinglesmith, "and we had to carry a lot of supplies each time." While supplies had to be ferried up the mountain, other items like



STATE-OF-THE-ART CCD images of galaxies such as M51 are taken in preparation for comet research.



computer tapes and garbage needed to be brought down.

Before each trip to the mountain, the astronomers ticked items off on a checklist: food, flashlight batteries, computer tapes, water, liquid nitrogen. "We ended up thinking through very carefully what we were going to do, how we would do it, and what we needed to do it with," says Klinglesmith. If something was forgotten, other members of the observatory team would backpack it up the mountain, weather permitting.

Under snowy conditions JOCR is a three-hour hike from the base of the mountain. "At worst it's five grueling hours through three or four feet of snow against forty- to sixty-mile-per-hour winds," says Shore.

Klinglesmith recalls that while he and observatory engineer Kevin Crain, a recent New Mexico Tech geophysics graduate, were up at JOCR, "Steve Shore and Carter Grotbeck, a New Mexico Tech physics student, would hike up with essentials that had been overlooked — a tool or batteries, a radio antenna, chocolate. These weren't worth the cost of an extra helicopter trip, but they were really needed on the mountain — especially the chocolate!"

Hazardous Cargo

The most ticklish cargo on the air-lifts was liquid nitrogen, which is used to keep the CCD chip at a stable temperature of -153°F . Stored in a 32-liter container that weighs over a hundred pounds when full, it is not only heavy but hazardous: in a closed container liquid nitrogen will vaporize and cause an explosion, so the container can only be loosely covered. When the containers are transported by helicopter, they are strapped in with seat belts.

The first twelve months of year-round operation at JOCR required

several person-years of effort to make the observatory run efficiently. This included finishing off the winterizing of the facility, getting the equipment set up and ready, and stockpiling food and supplies. "Now, day-to-day, nuts-and-bolts operations can go on at JOCR in the worst weather conditions," says Shore.

There were times during the first winter, however, when unexpected difficulties cropped up. When a frozen water pipe burst at JOCR, water for washing had to be pumped up from the 10,000-gallon water tank buried outside the observatory and carried in buckets. Drinking water had to be carried up the mountain in 5-gallon jugs. Occasionally the observatory crew even melted ice to wash dishes, though at 11,000 feet snow tends to vaporize rather than melt.

The astronomers spend two weeks at the observatory each month, beginning at Third Quarter Moon and ending at First Quarter. They have a flexible schedule, both to allow for unexpected events, such as equipment failures, and because of the limited conditions under which helicopters can fly. When the CCD failed last winter, a helicopter trip had to be scheduled at short notice to pick up the observatory crew.

Evacuation plans have been set up to deal with emergencies. There's a hierarchy of transportation: those in the best physical condition have to be prepared to walk if necessary, while others not in the best condition are the first to board the helicopter.

At such a remote site, redundancy — of equipment, power supplies, and people — is the key to successful winter operations. An absolute rule is that no one goes alone in winter. If the phones go dead, communications can continue via two-way radio. If the electricity fails, propane serves as a

back-up power source for heating, cooking, and lighting. The observatory will soon have a spare computer, in case of a breakdown.

Now that the observatory is operating year-round, detailed data have been collected about site conditions, including seeing, wind speed, temperature, and humidity. This information is not only essential for the astronomers to function on the mountain but it is also a critical factor in deciding whether much larger observatories should be built on the ridge.

Weather data collected at the site over the past two years show that the ridge is an excellent site for optical and infrared astronomy. "This is a mountain waiting for a large telescope," notes Klinglesmith. Several projects have been proposed that would place one or more large telescopes on the ridge. When one of those becomes a reality, JOCR will also benefit from improved access — a paved road — and shared operating expenses that would significantly reduce the "cost per astronomer per night." (See "Site Wanted: Three Domes, Stellar View" by Lys Ann Shore, August 1986.)

Until then, year-round operations will continue even at the cost of some hardship. "We feel that making the observatory a year-round facility is something that has to be done, both for the science and for our students' experience," Shore explains, "and that belief takes over when you face some of the tough jobs, like using ice axes to chop footholds on the icy road during a climb up the mountain." □

Lys Ann Shore is a writer and editor who lives in Socorro, New Mexico. Her most recent article, "Is Stellar Astronomy a Second-Class Science?," appeared in the October 1988 issue.

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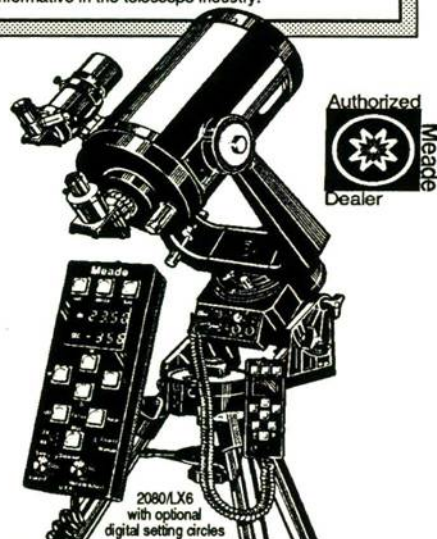


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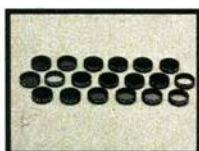


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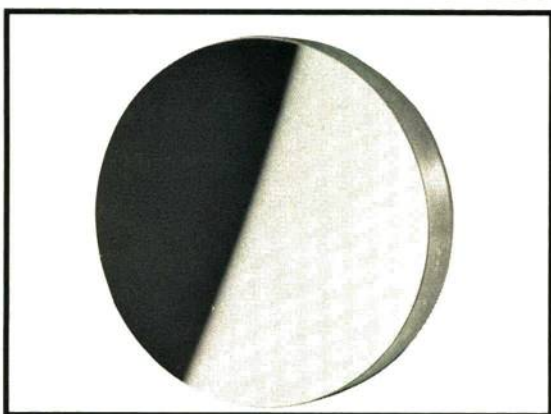


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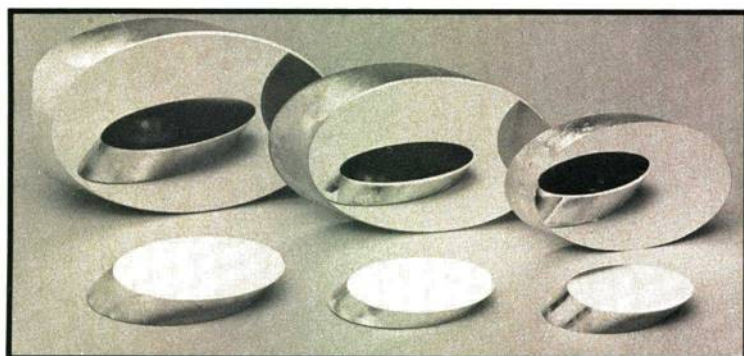
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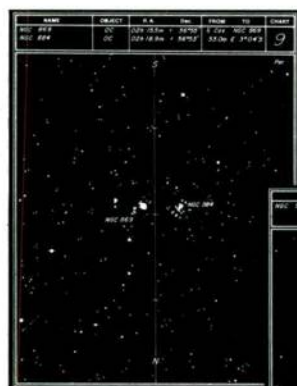
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North

The all-sky map shows
how the sky looks at:
10 p.m. on February 1
9 p.m. on February 15
8 p.m. on February 28
Planets are shown
at mid-month

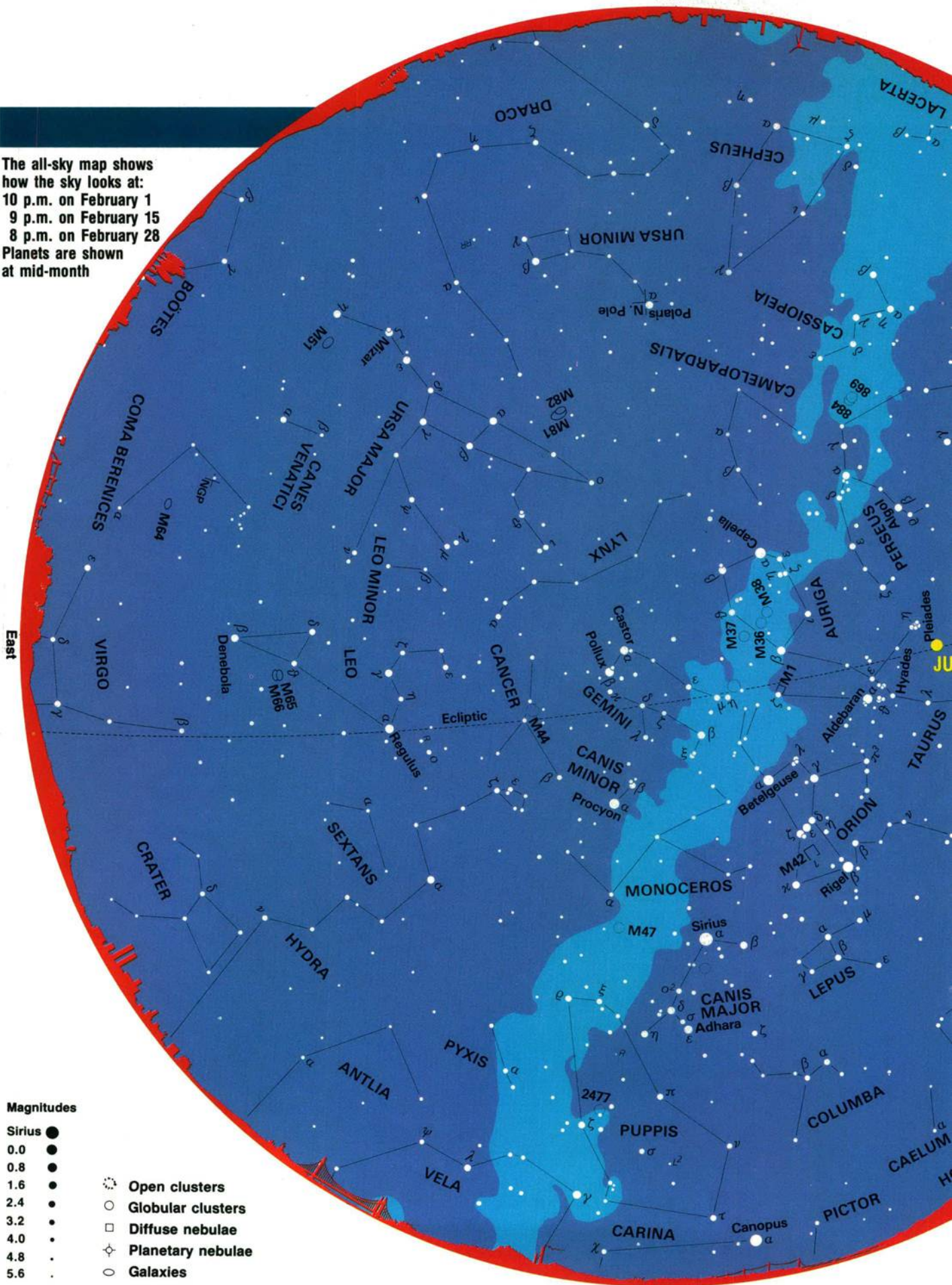
East

Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 ●
3.2 ●
4.0 ●
4.8 ●
5.6 ●

- Open clusters
- Globular clusters
- Diffuse nebulae
- ◇ Planetary nebulae
- Galaxies

South



Sky Almanac

FEBRUARY 1989

LUNAR ECLIPSE ON FEBRUARY 20

Viewers in Alaska, Hawaii, and points west can see a total lunar eclipse on the morning of February 20. Those in the western United States and western Canada will be able to witness the early stages of the eclipse.

MERCURY VISIBLE IN THE MORNING

The planet Mercury appears low in the eastern predawn sky this month. The best time to view the elusive planet is in the week around mid-month, thirty to forty-five minutes before sunrise.

JUPITER CASTS A LARGE SHADOW

The shadow of Jupiter stretches as far east of the giant planet as it can this month. This means telescopic observers will see eclipses of the Galilean satellites occur as far from Jupiter as possible.

THE REDDENING OF MIRA

Mira, the most famous of variable stars, continues to fade in February. But observers with large-aperture telescopes can follow one of the more intriguing aspects of this diminution: Mira appears progressively redder as its magnitude drops.

Dates and Times

- | | |
|--|---|
| 1 The Moon passes 0.7° south of Antares, 6 a.m. EST | 18 Mercury at greatest western elongation (26°) |
| 3 The Moon passes 5° south of Saturn, 10 a.m. EST | 20 The Moon passes 0.02° north of Regulus, 6 a.m. EST
Full Moon, 10:32 a.m. EST, and lunar eclipse
Juno at opposition |
| 6 New Moon, 2:37 a.m. EST | 23 Moon at apogee (252,242 miles from Earth) |
| 7 Moon at perigee (224,275 miles from Earth) | 25 Pallas in conjunction with Sun |
| 9 Iris at opposition | 28 The Moon passes 0.7° south of Antares, 2 p.m. EST
Last Quarter Moon, 3:08 p.m. EST |
| 11 Jupiter at quadrature | |
| 12 The Moon passes 4° north of Mars, 2 a.m. EST
First Quarter Moon, 6:15 p.m. EST | |

Map Art by Wil Tirion

Sky Almanac

Southern Edition

APRIL: JUPITER LOSES GROUND

The Wanderers

The two bright planets of the evening — Mars and Jupiter — remain conspicuous among the stars of Taurus, although **Jupiter** is losing ground to the Sun faster than Mars and will soon be gone. In fact, April is the last month to get a good look at Jupiter, because by the end of May evening twilight will have overtaken it.

Telescopically Jupiter spans 34", with two dark bands paralleling its equator. Look for irregularities in the bands' edges. Flanking the dusty-white disk are its four brightest moons (Io, Europa, Ganymede, and Callisto). Their motions as they revolve around Jupiter mimic those of the planets around the Sun. The discovery of these moons in 1610 by Galileo with his new 30x telescope lent powerful support to "Copernicans" everywhere.

Although **Mars** stands higher than Jupiter, it offers no such fine views because its disk measures only 4" to 5" across — about the same as a small lunar crater. Nonetheless, repeated viewing will reveal dusky markings slowly parading across the disk.

Mercury passes through superior conjunction on 4 April but won't appear in the evening sky until the last week of the month. Look for it a few degrees above the northwestern horizon. This is the beginning of the year's worst apparition for Mercury and it is also the briefest: Mercury will vanish again into the Sun's glare before the middle of May.

The morning sky contains three more planets, but of them only **Saturn** is easily visible to the naked eye. As dawn lightens, Saturn stands almost overhead, shining at magnitude 0.5 amidst the stars of Sagittarius. With its north pole rolled down 25° toward us, Saturn and its 38"-wide ring system present a breathtaking

sight. As dawn turns the sky around it blue, Saturn will take on the color of pale honey.

Engaged this year in a triple conjunction with **Neptune**, Saturn makes an excellent step-off point for finding that planet. At 8th magnitude, Neptune lies about 6' or 7' north of Saturn and a degree and a half west. Insert a low-magnification eyepiece, center the scope on Saturn, and slowly offset in the right directions. Look carefully for a "star" that isn't quite a pinpoint, and then slip in a high-power eyepiece to confirm that you've found Neptune. It has a 2.2" bluish grey disk.

At magnitude 5.6, **Uranus** is just bright enough to be visible to the naked eye, but identifying it for certain calls for telescopic magnifications. It is nearly stationary in Sagittarius about 1° north of M28, a small globular cluster northwest of Lambda (λ). Uranus has a disk 3.7" across and looks startlingly blue-green.

The Starry Sky

The end of evening twilight shows **Orion** in the trees on the western horizon with his hound **Canis Major** poised above him. Sirius, the Dog's brightest star, flashes colorfully as it sets.

Across the northern sky the ecliptic traces a line through the zodiac. Prominent tonight is **Leo** the Lion, a crouching feline with bright Regulus in its forepaws. Leo's head and mane form a crook opening westward toward dim **Cancer** the Crab. Leo's hindquarters form a right triangle.

East from Leo, the Maiden **Virgo** reclines with Spica gleaming as an ear of wheat in her hand. Below Virgo, nonzodiacal **Coma Berenices** (Berenice's Hair)

and **Bootes** the Herdsman describe a low arc over the horizon. Coma and Virgo are home to dozens of galaxies, targets for medium or large telescopes.

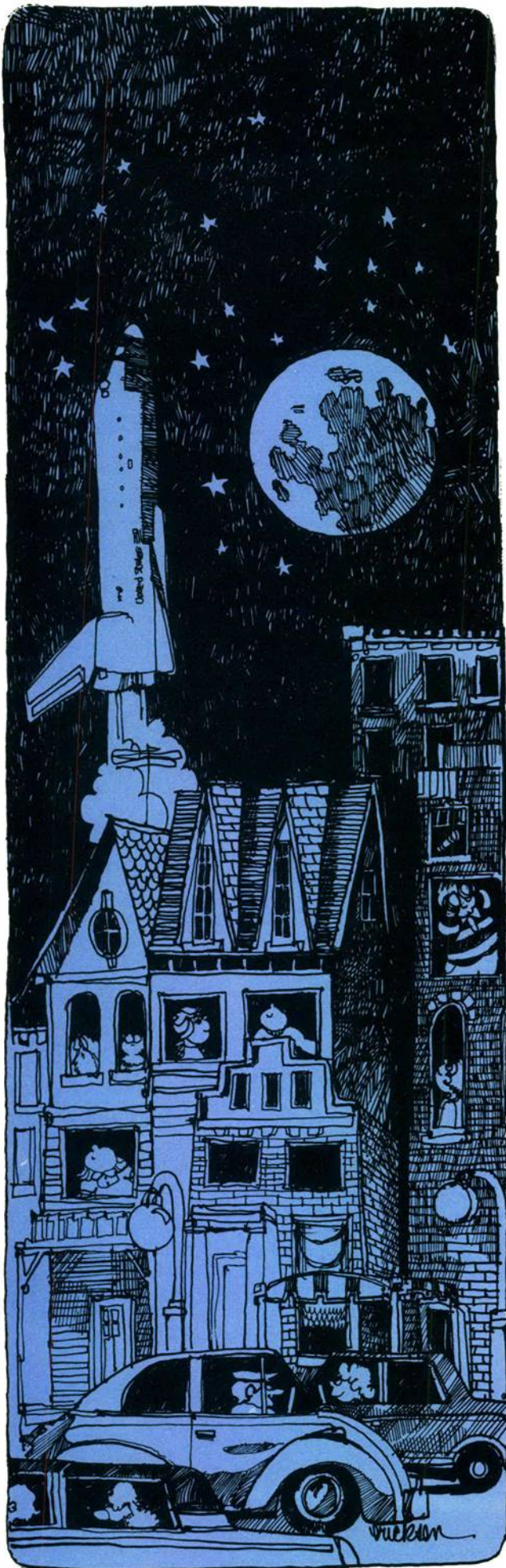
South of Leo and Virgo, the Water Snake **Hydra** zigzags from west to east. Its head is a small oblong near Cancer and its tail lies next to zodiacal **Libra** the Scales, east of Virgo. On the snake's back perch a Cup **Crater** and a Crow **Corvus**.

The zodiac meets the Milky Way in **Scorpius** the Scorpion, an easy-to-find figure resembling its name. Its brightest star was named Antares, Greek for "the rival of Ares," because its color resembles that of Mars. (Ares = Mars in Greek.)

The Milky Way is delightful by naked eye but breathtaking in binoculars or a low-power telescope. Scan its length slowly for unforgettable views of nebulae and star clusters. Below Scorpius in the east the Archer **Sagittarius** is rising (with guest planet Saturn). The cluster marked M6 on the map lies close to the direction of the center of the Milky Way Galaxy, hidden behind thousands of light-years of dusty gas.

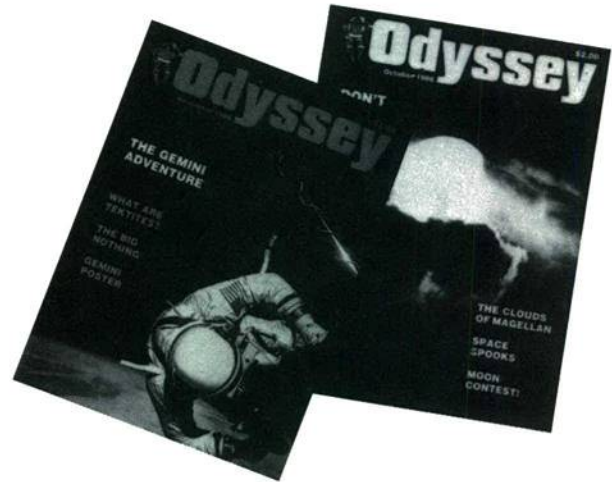
Moving northwest up the Milky Way, you pass **Ara** the Altar and **Norma** the Surveyor's Level. **Lupus** the Wolf is conspicuous, standing on a promontory jutting from the Milky Way with its stars adjoining those of **Centaurus** the Centaur. Half-man, half-horse, the Centaur is stepping nimbly over the Southern Cross **Crux**, a stellar jewel box without compare.

Sailing the Milky Way overhead, the great ship **Argo** comprises four constellations: polygonal **Vela** forms the Sails, crooked **Carina** makes a Keel, angular **Puppis** is the Stern, and faint **Pyxis** is a Compass to keep **Argo** on course. Though bright, the field of stars here is crowded and these figures can be hard to trace. The only real stellar beacon is Canopus in Carina. — Robert Burnham



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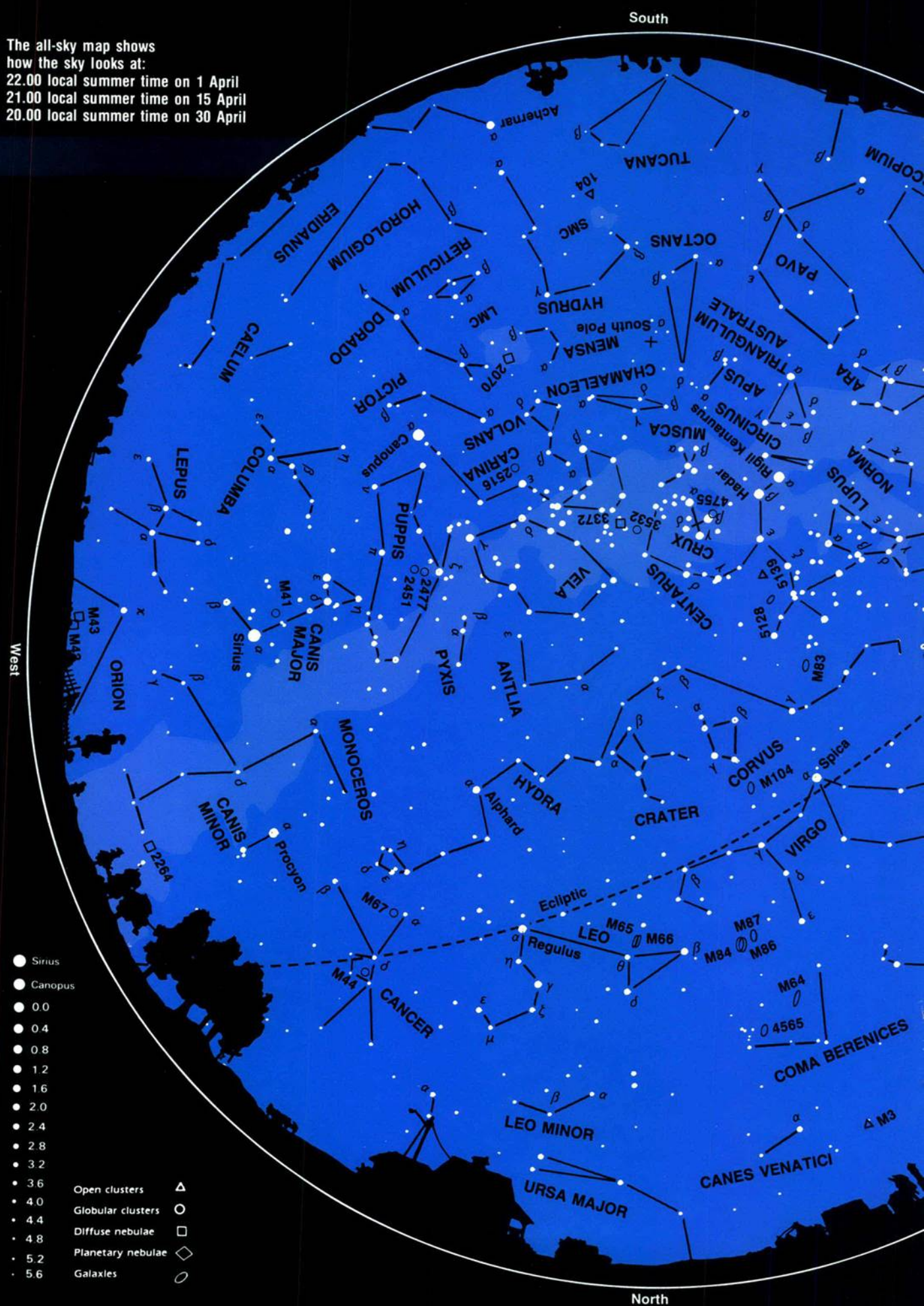
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The all-sky map shows
how the sky looks at:
22.00 local summer time on 1 April
21.00 local summer time on 15 April
20.00 local summer time on 30 April



APRIL 1989

MOON OVERTAKES JUPITER AND MARS

As the Moon slips eastward through Taurus in the evening sky, it passes Jupiter on the 9th and Mars on the 10th. Both planets plus the Pleiades and Hyades star clusters make a pretty collection of bright objects for following the Moon's motion.

MOON OCCULTS REGULUS

On 15 April the gibbous Moon will move in front of Regulus, the 1st-magnitude star marking the forepaws of Leo the Lion. In the Southern Hemisphere the event (which takes place near 23 UT) is visible only from southwestern Africa.

MOON OCCULTS ANTARES

Nine days after occulting Regulus, the Moon moves through the Scorpion, where it occults 1st-magnitude Antares, the insect's ruddy "heart star," at around 7 UT on the 24th. The event can be seen over the southern Pacific Ocean, southern South America, the Antarctic, and far southern South Africa.

SATURN OVERTAKEN BY THE MOON

On 26 April, two days before Last Quarter, the Moon sweeps past Saturn, high in the predawn sky. Both are in Sagittarius, and the Moon lies 5° due south of Saturn at 23 UT.

East

Dates and Times

- | | |
|---|--|
| 4 Mercury and Venus in superior conjunction | 21 Full Moon, 3h13m UT |
| 5 Moon at perigee (357,192 kilometers from Earth) | 23 Saturn stationary |
| 6 New Moon, 3h33m UT | 24 Antares is occulted by the Moon for observers in the southern Pacific Ocean, southern South America, Antarctica, and extreme southern Africa, 7 UT |
| 10 The Moon passes 4° north of Mars, 9 UT | 26 The Moon passes 5° south of Saturn, 23 UT |
| 12 First Quarter Moon, 23h13m UT | 28 Ceres in conjunction with Sun |
| 15 Regulus is occulted by the Moon for Southern Hemisphere observers in southwestern Africa, 23 UT | Last Quarter Moon, 20h46m UT |
| 18 Moon at apogee (406,167 kilometers from Earth) | |

Richard Berry
Jeff Kanipe
Thomas L. Hunt
Todd Graveline

Computer Plotting
Map Content
Design
Design

THE MOON IN ECLIPSE

On February 20 the Moon slides through Earth's shadow, creating a total lunar eclipse for about half the world. All or most of the eclipse is visible from Asia, Australia, the Arctic, and the Pacific, while people in parts of North America, Europe, and Africa can see some of the eclipse. For those in the western United States and western Canada, the Moon sets that morning while it is immersed in the darkest part of Earth's shadow. (See "A Picture-Perfect Lunar Eclipse" by David J. Eicher on page 78.)

LAST CHANCE TO CATCH VENUS

When February begins, Venus is visible against a background of bright morning twilight. Each succeeding day it rises closer to the time of sunrise. Any other planet would be drowned in the light of dawn, but not Venus. It is so brilliant it can be seen even in a very bright sky.

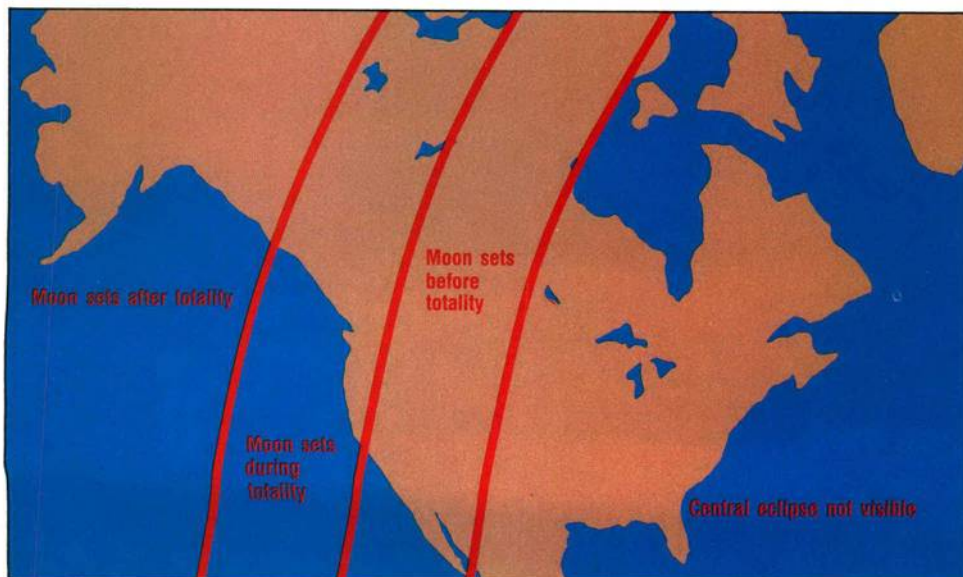
Venus disappears from the eastern predawn sky sometime around the end of this month. It is leaving the morning sky because it is now far ahead of Earth in its smaller orbit around the Sun. This month Venus is seen over a distance of some 155 million miles. Even so, at magnitude -3.9 , it shines brightly enough to pierce the twilight glow. When will you last see Venus with the eye? Can you follow it with binoculars for some days after that?

The exact day on which you last see Venus depends on several conditions: a southerly latitude, a clear eastern horizon, pure country air, and binoculars all can help you track the planet well into the dawn. It's best if you observe regularly; look carefully on consecutive days throughout the month. But be aware that a spell of cloudy weather can ruin your best plans. That happened to me last spring just before Venus passed between Earth and the Sun. I had been watching the planet in the evening sky, missed it for a few days in a row because of clouds, and walked out of a restaurant one evening feeling alarmed because Venus was nowhere to be seen. Not that I hadn't expected it to disappear. Not that I didn't know it would return in a few weeks to the morning sky. It was just that I felt I had missed something.

This month's disappearance is somewhat different from the one last spring, because then Venus was passing between the Sun and Earth and now it is about to pass behind the Sun. It will take Venus much longer to reappear from the Sun's glare this time. We won't see the planet again until the middle of May, when it will be low in the northwestern evening sky.



EARTH'S SHADOW will darken the Moon for observers in western North America on February 20. Tom Greska photographed the December 1982 lunar eclipse from Lockwood Valley, California (above).



MERCURY CLIMBS FROM THE MURK

Mercury begins the month near Venus in the east before dawn. The two worlds are closest on the morning of February 1. On that date Venus is still easy to see, but Mercury at magnitude $+1.7$ is more than 150 times fainter. You will have to look carefully or use binoculars to see Mercury in the twilight glare.

As Venus drops into the dawn, however, Mercury climbs out of it. This month's apparition of Mercury is a fairly good one: the planet lies 26° from the Sun on February 18. Look for Mercury low in the east thirty to forty-five minutes before sunrise around the middle of the month.

SEEING THE ELUSIVE ZODIACAL LIGHT

February and March are the best months for seeing the ethereal milky white glow of the zodiacal light in the evening sky. It may be seen in the west after the last glow of twilight has disappeared.

Many people see the zodiacal light and ignore it, because they imagine it to be an extension of ordinary twilight or the glow of a city beyond the horizon. But the zodiacal light is a far more exotic phenomenon. While twilight is an atmospheric effect, the zodiacal light originates in outer space. The light is actually sunlight reflecting off dust grains that move in the plane of the solar system.

Look for the zodiacal light on a moonless night from a dark location. It looks like a huge, luminous pyramid, widest at the horizon and tapering as it extends high in the west after twilight's end. At its brightest the zodiacal light is slightly brighter than the summer Milky Way.

FEBRUARY'S PLANETS

Mars is high in the south when night begins. It is still fairly bright in February but fades from magnitude +0.6 on the 1st to magnitude +1.0 on the 28th. Mars is growing fainter as we rush ahead of it in our smaller, faster orbit around the Sun. During February Mars' distance from Earth increases from less than 120 million miles to over 140 million miles.

Mars appears amongst the sparse background of the constellation Aries during February. At the beginning of March it will cross into the next zodiacal constellation, Taurus.

There it will encounter a much brighter planet, Jupiter, which has dawdled in Taurus for many months now. Mars will pass just 2° north of the giant planet in March. Throughout February you can track the faster motion of Mars against the star background as the Red Planet edges closer to Jupiter. The bright star Aldebaran also lies in this region of the heavens, and its orange color provides an interesting contrast with ruddy Mars. Notice also that Aldebaran twinkles, while Mars shines steadily.

Jupiter, meanwhile, shines much more brightly than Mars at magnitude -2.4. Seeing the two together makes last September — when Mars briefly shone brighter than Jupiter — seem a long time ago.

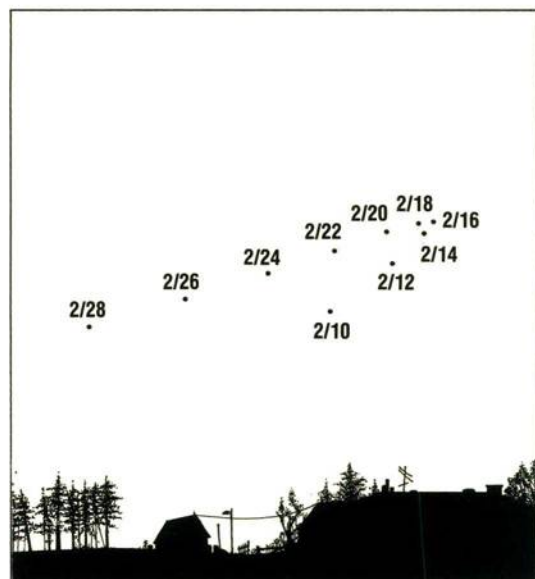
Jupiter is still lingering in the vicinity of Taurus' two great star clusters, the Pleiades and Hyades. It will remain in Taurus until it disappears in the Sun's glare in late May. About a month later Jupiter will reappear before dawn, cross into Gemini, and head on to opposition a few days before year's end.

Saturn rises nearly two hours before the Sun when February begins. By early March it will be rising nearly four hours before the Sun. The planet is an inconspicuous golden "star" in the constellation Sagittarius. It is the same brightness — magnitude +0.6 — as Mars in early February.

Unlike Mars, however, Saturn lies in the most star-cluttered region of the heavens, in the general direction of the center of our Milky Way Galaxy. Saturn will get brighter as it nears its July opposition, but for now the planet appears to the eye as just another "face" in the crowd of stars located in that region.

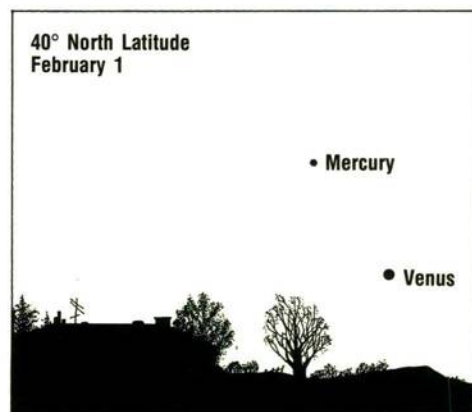
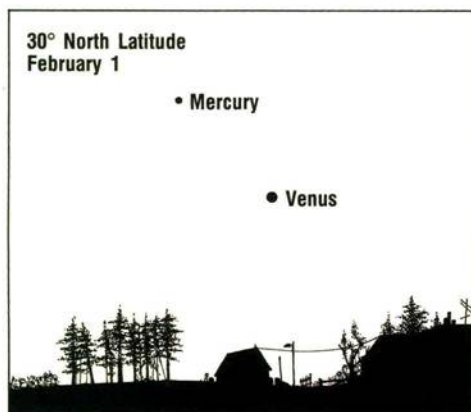
Venus remains the brightest planet in the sky, but it appears less brilliant now than for many months past because it lies very low in the eastern predawn sky. The planet rises increasingly closer to the Sun throughout February and disappears in the twilight glow sometime in late February or early March.

When February begins, Mercury lies very near Venus, but it is so much fainter that you may have



MERCURY RISES into view shortly before the Sun this month in the east-southeast. Look for the elusive planet 3° above the horizon thirty to forty-five minutes before sunrise.

VENUS DISAPPEARS in the morning twilight late this month. Your chances of seeing the planet improve as you head south: At the beginning of civil twilight Venus appears twice as high from 30° latitude as it does from 40° latitude.



difficulty seeing Mercury in the twilight sky. The innermost planet grows brighter as it climbs higher in the east before dawn, however, and you should see it easily around the middle of the month.

FEBRUARY'S STARRY SKY

This month offers a challenge and a promise concerning a star many of you can't see! The star is Canopus in the constellation Carina, which is located so far south on the celestial sphere it can't be seen from the more northerly latitudes of the Northern Hemisphere.

Those in southerly latitudes, however, can see this star — the second brightest in the sky. From where I live in central Texas, Canopus appears on winter evenings as a bright light cutting a low arc across the southern sky.

Whether or not you can see it from your latitude (you need to be south of latitude 35° north, approximately), Canopus has a name and legend you should know. The second-brightest star after Sirius, Canopus is located almost due south of Sirius on the celestial sphere. When Sirius is at its highest in the south on winter evenings, Canopus lies almost directly below it.

As seen from the United States, Canopus' brilliance is dimmed somewhat by the great amount of air through which we peer at it.

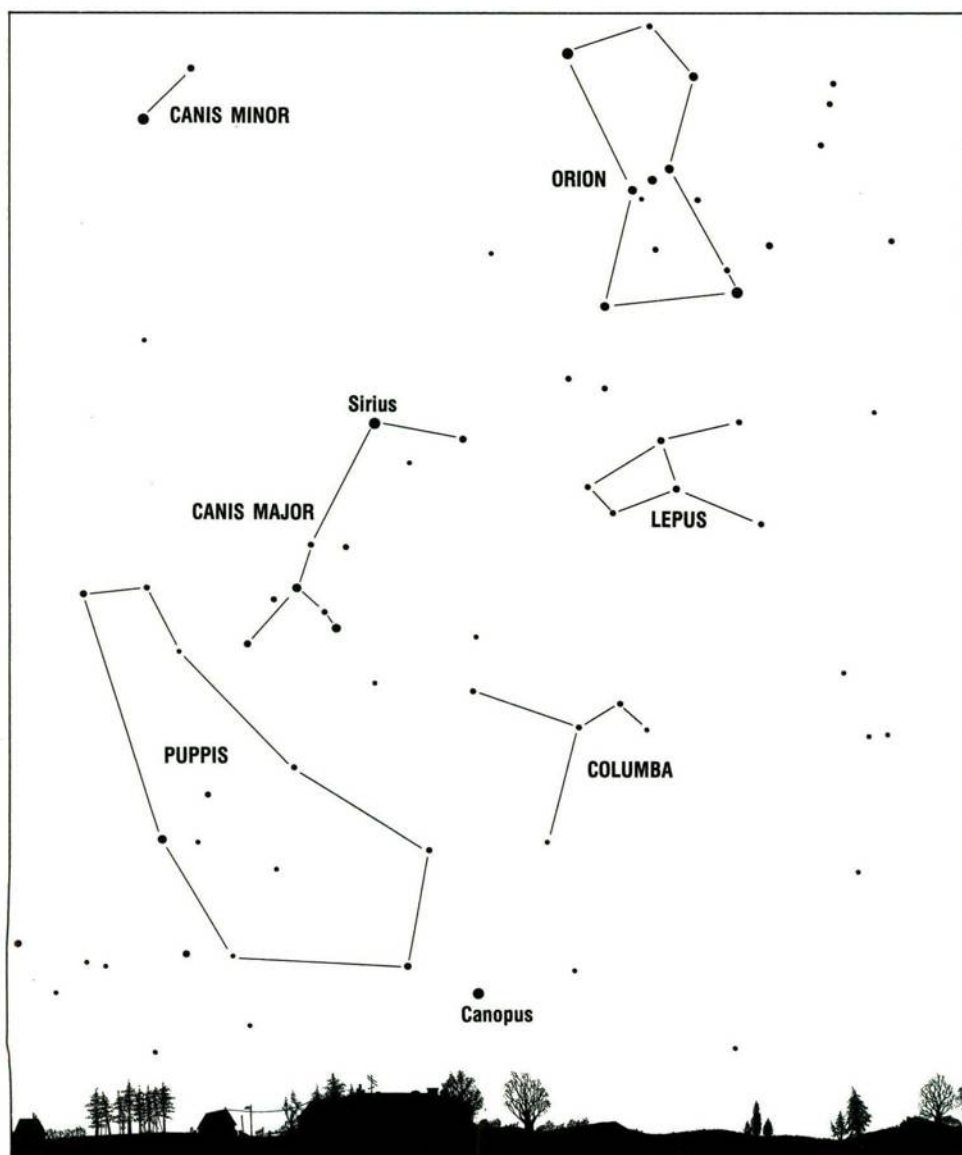
To Southern Hemisphere observers, however, Canopus and Sirius look very different. From there, the two brightest stars ride high in the sky and appear like brilliant twin beacons.

Canopus was named for the chief pilot of the Greeks in Homer's *Iliad*. Its name is appropriate because this brilliant star has long been used in navigation. In fact, Canopus has become a navigational star in the space age. Many interplanetary spacecraft on their way to neighboring worlds "lock on" to Canopus to stabilize themselves.

But I said there was a challenge and a promise concerning the sky's second-brightest star. The challenge is simply to remember it and look for the star if you live in a southern state or if you're ever in the south on a winter evening. Canopus is easy to see if you're far enough south because it's so very bright.

The promise is that when you see it, you'll be glad you looked. No other star so readily calls to mind the many mysteries below the southern horizon that are hidden from the view of northern observers. On seeing Canopus you may wish, as I sometimes do, that Earth could be transparent for just one night. Then we could glimpse that hidden universe of stars that lies beneath our feet, obscured by the world on which we stand. □

GLITTERING LIKE A JEWEL in the winter evening sky, Canopus is a beautiful sight for observers in the southern United States. Look for the second-brightest star in the sky in the south, below Sirius, in the early evening.



FOLLOW JUPITER'S EVER-CHANGING SATELLITES

Jupiter reaches quadrature in February, one month after Mars reached the same point in its orbit. This means Jupiter appears 90° from the Sun in our sky, and the planet's shadow extends as far east of the planet's disk as it can. Quadrature has its most obvious effect on the telescopic appearance of Jovian satellite phenomena — eclipses, occultations, and transits. The phenomena will appear noticeably different this month than they did when I last mentioned them in October.

The innermost Galilean satellite, Io, orbits close enough to Jupiter that it enters Jupiter's shadow as the satellite is occulted by the planet's disk. Thus, an observer will see Io first occulted by Jupiter's disk and then reappear from eclipse about three-and-a-half hours later. Europa and Ganymede orbit farther away and both are occulted by Jupiter's disk before their eclipses begin. (Ganymede reappears from behind Jupiter's disk only fifteen to twenty minutes before the moon is eclipsed.)

The shadows of the Jovian satellites also point farthest to the east this month. Through a telescope Io first appears in front of Jupiter's disk, then Io's shadow falls on Jupiter, next the satellite's disk moves off Jupiter's disk, and finally Io's shadow clears the Jovian disk. For Europa and Ganymede the transits of the satellites' disks finish before the eclipses begin.

Finally, Callisto continues to pass north and south of Jupiter and does not exhibit any transits, occultations, or eclipses. Our view of Callisto's orbit is slowly changing, however, and by October the outermost Galilean satellite will begin a series of occultations and transits. The table at right lists the phenomena most easily seen from North America this month.

If you observed Mars last month, you saw that quadrature gave the Red Planet a distinctly gibbous shape. As Jupiter reaches quadrature on February 11, you should see a darkening of Jupiter's eastern limb, but nothing like the definite phase effect you saw on Mars. The reason for this difference is that Jupiter lies over three times more distant from Earth than Mars, so the angle between the Sun, Jupiter, and Earth is much smaller than the angle between the Sun, Mars, and Earth. We simply cannot see enough of the nightside of Jupiter to observe a true phase effect. Instead, we see only a darkened sunrise line.

MIRA FADES AND BECOMES REDDER

In December's column I described the pulsating variable star Mira (Omicron [o] Ceti) in detail. During late November and early December Mira reached its maximum brightness and then began to fade. If Mira follows a typical pattern — and it does not always — it should drop below the limit of naked-eye visibility in late February.

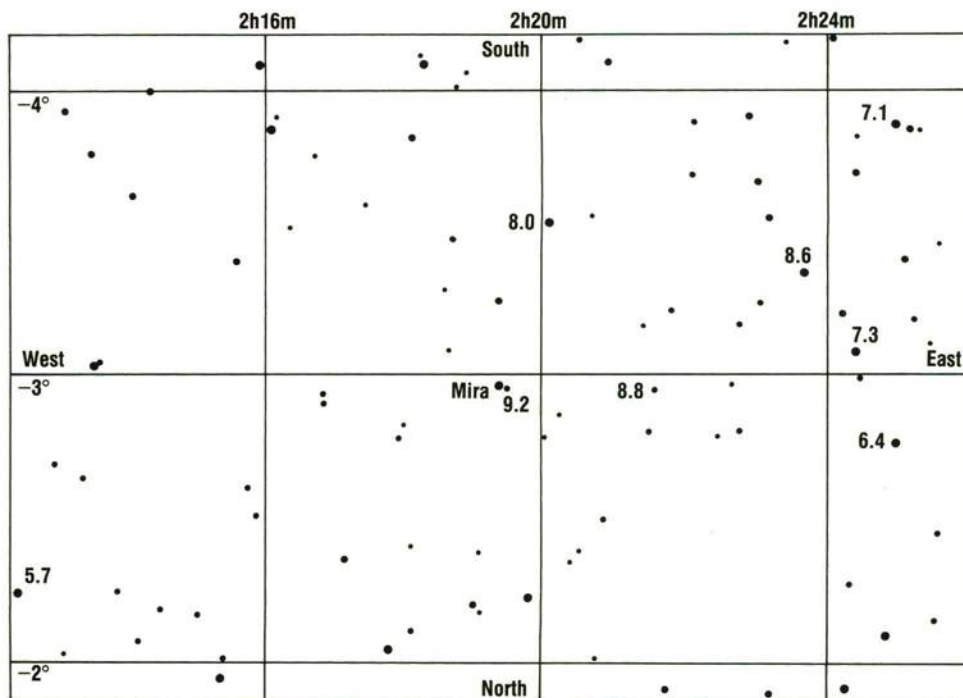
Fortunately Mira never fades beyond the light-gathering grasp of a small telescope. If you're interested in following Mira and estimating its magnitude this winter and spring, use the chart at right. It shows eight stars located near Mira with magnitudes that range from 5.7 to 9.2, a range that allows you to follow the star as it fades to minimum over the next several months. If you enjoy

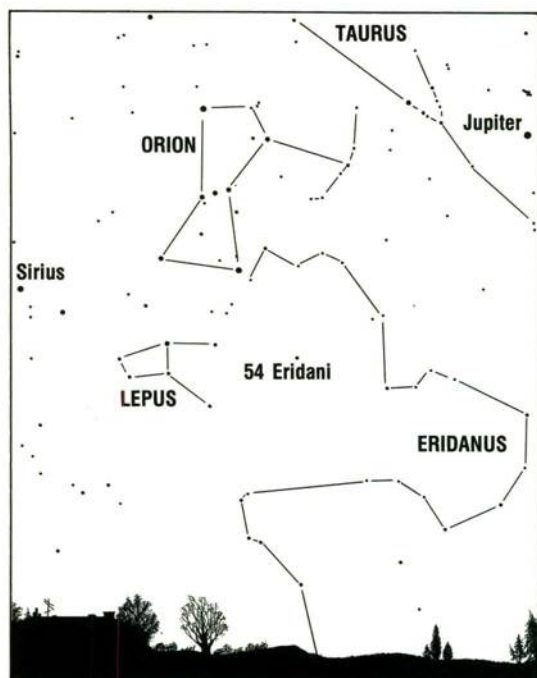
JOVIAN SATELLITE PHENOMENA

Date	Event	Time
IO		
Feb. 7	Occultation Begins	2:44
	Eclipse Ends	6:13
Feb. 15	Transit Begins	1:49
	Shadow Enters	3:08
	Transit Ends	3:59
	Shadow Leaves	5:18
EUROPA		
Feb. 5	Occultation Begins	1:20
	Occultation Ends	3:42
	Eclipse Begins	4:00
	Eclipse Ends	6:22
Feb. 21	Transit Begins	1:36
	Transit Ends	3:56
	Shadow Enters	4:13
	Shadow Leaves	6:33
GANYMEDE		
Feb. 17	Transit Begins	1:14
	Transit Ends	3:35
	Shadow Enters	6:38
	Shadow Leaves	8:55
Feb. 28	Eclipse Begins	0:40
	Eclipse Ends	3:01

This table lists Jovian satellite phenomena visible from North America. Times given are in universal time.

MIRA CONTINUES TO FADE over the next several months. Compare the variable star's magnitude with the magnitudes of nearby stars given in the chart below.





OBSERVE MERCURY in the daytime by locating 4th-magnitude 54 Eridani in your telescope the evening before and allowing Earth's rotation to bring the planet into view.

observing Mira and would like to help monitor this or other variable stars, consider joining the American Association of Variable Star Observers at 25 Birch Street, Cambridge, MA 02138.

While a small telescope lets you follow Mira's changing brightness, a large-aperture telescope — 12 inches or larger — can show you another interesting facet of Mira's variability: as Mira fades in brightness, it also grows redder. Stars that appear almost colorless in small telescopes take on vivid colors in larger scopes.

The color changes for the same reason that the star fades — the falling temperature of the star. Mira's surface temperature drops from about 2500 to 1900 kelvins as it fades from maximum to minimum brightness. At minimum brightness most of the visible radiation Mira emits lies at the far red end of the optical spectrum, so Mira appears noticeably redder.

OBSERVING MERCURY IN THE DAYTIME

Mercury reaches greatest western elongation on February 18, when it is 26° from the Sun. Unfortunately the 26° along the ecliptic don't translate into much altitude, because the ecliptic makes a shallow angle to the morning horizon at this time of year. Thus, observing Mercury in a dark sky won't be easy this month. With a little preparation, however, you can observe Mercury during the day.

There are two methods of sighting Mercury in daylight. If you have an altazimuth telescope, you need to find a star with a declination very close to Mercury's declination that is visible in the evening sky. The star 54 Eridani (see the map at left) — located at right ascension 04h40.4m and declination $-19^\circ 40'$ — fits the bill during the middle ten days of the month. On the evening before you plan to observe Mercury, find 54 Eridani with your lowest-power eyepiece and place the star about half a degree south of the center of your telescope's field of view.

Note the exact time the star is in the proper position in your telescope's field. Then carefully cover your telescope, making sure not to shift its position. Mercury will appear in the eyepiece at the time given by the difference in right ascensions of the two objects. So, subtract the right ascension of 54 Eridani from that of Mercury (see table below) and add the result to the time when 54 Eridani was in the field of view. Next, subtract 24 hours from this time to give a result between 0 and 24 hours, and then subtract 2 minutes to account for the fact that sidereal time is 4 minutes faster per day than civil time. (You'll be looking for Mercury about 15 hours, or roughly half a day, later than the time you

observed 54 Eridani.) Begin looking for Mercury about five minutes before the appointed time. If you've done everything right and no clouds or earthquakes interfere, you should see Mercury's disk drift slowly into the field of your telescope!

You can follow the same procedure if you own an equatorial telescope, or — if the telescope's polar axis is aligned precisely — you can take advantage of the scope's setting circles to dial in the position of Mercury. The simplest way to do this is by finding the Sun's position for the day you want to observe (see table). Center the Sun in the telescope's field, *making sure* you use a proper filter on your telescope and secure the cap on the finder. If you don't

POSITIONS OF MERCURY AND THE SUN

Date	Mercury R.A. (2000) Dec.	Sun R.A. (2000) Dec.
Feb. 1	19h54m35s $-17^\circ 29' 27''$	21h01m57s $-16^\circ 54' 27''$
Feb. 3	19h51m22s $-17^\circ 56' 23''$	21h10m04s $-16^\circ 19' 19''$
Feb. 5	19h50m29s $-18^\circ 20' 12''$	21h18m07s $-15^\circ 43' 02''$
Feb. 7	19h51m41s $-18^\circ 40' 13''$	21h26m07s $-15^\circ 05' 41''$
Feb. 9	19h54m42s $-18^\circ 55' 59''$	21h34m04s $-14^\circ 27' 19''$
Feb. 11	19h59m17s $-19^\circ 07' 11''$	21h41m58s $-13^\circ 47' 59''$
Feb. 13	20h05m10s $-19^\circ 13' 35''$	21h49m49s $-13^\circ 07' 46''$
Feb. 15	20h12m09s $-19^\circ 15' 03''$	21h57m37s $-12^\circ 26' 41''$
Feb. 17	20h20m03s $-19^\circ 11' 28''$	22h05m22s $-11^\circ 44' 49''$
Feb. 19	20h28m42s $-19^\circ 02' 44''$	22h13m04s $-11^\circ 02' 13''$
Feb. 21	20h37m59s $-18^\circ 48' 51''$	22h20m43s $-10^\circ 18' 56''$
Feb. 23	20h47m48s $-18^\circ 29' 45''$	22h28m20s $-09^\circ 35' 00''$
Feb. 25	20h58m04s $-18^\circ 05' 26''$	22h35m54s $-08^\circ 50' 30''$
Feb. 27	21h08m42s $-17^\circ 35' 54''$	22h43m26s $-08^\circ 05' 28''$

Daylight observations of Mercury are possible with a polar-aligned equatorial telescope that is offset from the Sun's position. Positions are given for 18 UT.

have a filter, project the Sun's image on a card with your lowest-power eyepiece. (To avoid damaging the eyepiece, project the Sun for only a few minutes.) With the Sun still in the center of the field, set the circles to the Sun's position for that date. Then immediately move the telescope so the circles read Mercury's position for that date. Remove the filter and look for Mercury in the eyepiece.

You may be surprised at how well you can see Mercury. Furthermore, you can also observe the other naked-eye planets and the twenty-one 1st-magnitude stars in the daytime with the same techniques.

TELESCOPIC PLANETS

Although the lunar eclipse on February 20 offers little to telescope owners in the continental United States, observers in Hawaii will have an added treat that morning: Approximately two hours before the eclipse begins, the Moon occults the 1st-magnitude star Regulus. For more details see "A Picture-Perfect Lunar Eclipse" by David J. Eicher, page 78.

At the beginning of February Venus rises about forty-five minutes before the Sun. Only its extreme brilliance (magnitude -3.9) allows us to see the planet at all this month. It should disappear into the solar glare during the latter half of February. If you've been drawing Venus throughout this apparition, now is the time to assemble your montage of drawings — the final entries from this month will show a 10"-diameter disk about 98 percent illuminated.

The disk of Mars shrinks from 7.4" in diameter at the beginning of the month to 6.1" on the 28th. For this reason only very steady seeing, high powers, and an aperture of 6 inches or more will show much detail on the Red Planet. On the chance that you might get lucky, however, you should give Mars a quick look if the seeing appears good.

In addition to the satellite phenomena mentioned earlier, look for Jupiter's prominent cloud features this month. Several observers have noticed that Jupiter's Great Red Spot turned slightly redder over the summer and fall, so it may be worth viewing this winter. Jim van Nuland of the San Jose Astronomical Association wrote that in September he found "the Great Red Spot readily, nestled into the southern edge of the South Equatorial Belt. The belt material preceding the Spot is wider and darker than that following, so the Red Spot Hollow has an asymmetrical appearance." Jim also noted that the Red Spot appeared orange or salmon pink in color.

Saturn, Uranus, and Neptune all crept into the morning sky late in January, so you'll have to get up early to see the trio of gas giants this month. Uranus leads the group, rising about two hours before the Sun on the 1st and three-and-a-half hours before the Sun on the 28th. Saturn and Neptune lag behind Uranus by twenty to twenty-five minutes.

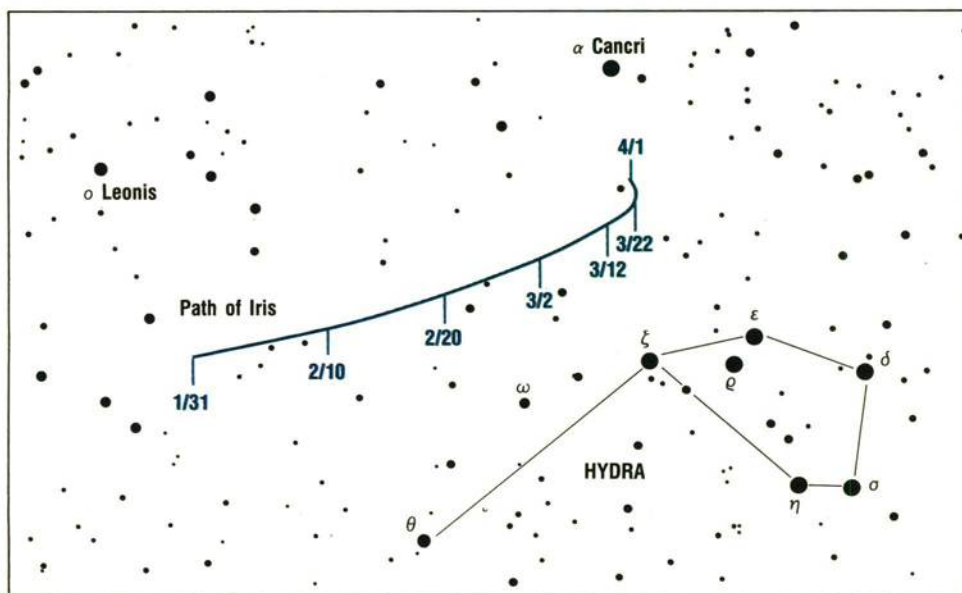
ASTERIODS IN THE EYEPIECE

Asteroid 7 Iris reaches opposition on February 9, when it is an 8.4-magnitude speck near the border of Leo, Cancer, and Hydra. Use the finder chart or table of coordinates at right to locate Iris's position and then observe that area at low magnification and sketch or photograph what you see. If you make the same observation a night or two later, you'll notice a point of light that has changed position. That's Iris. □

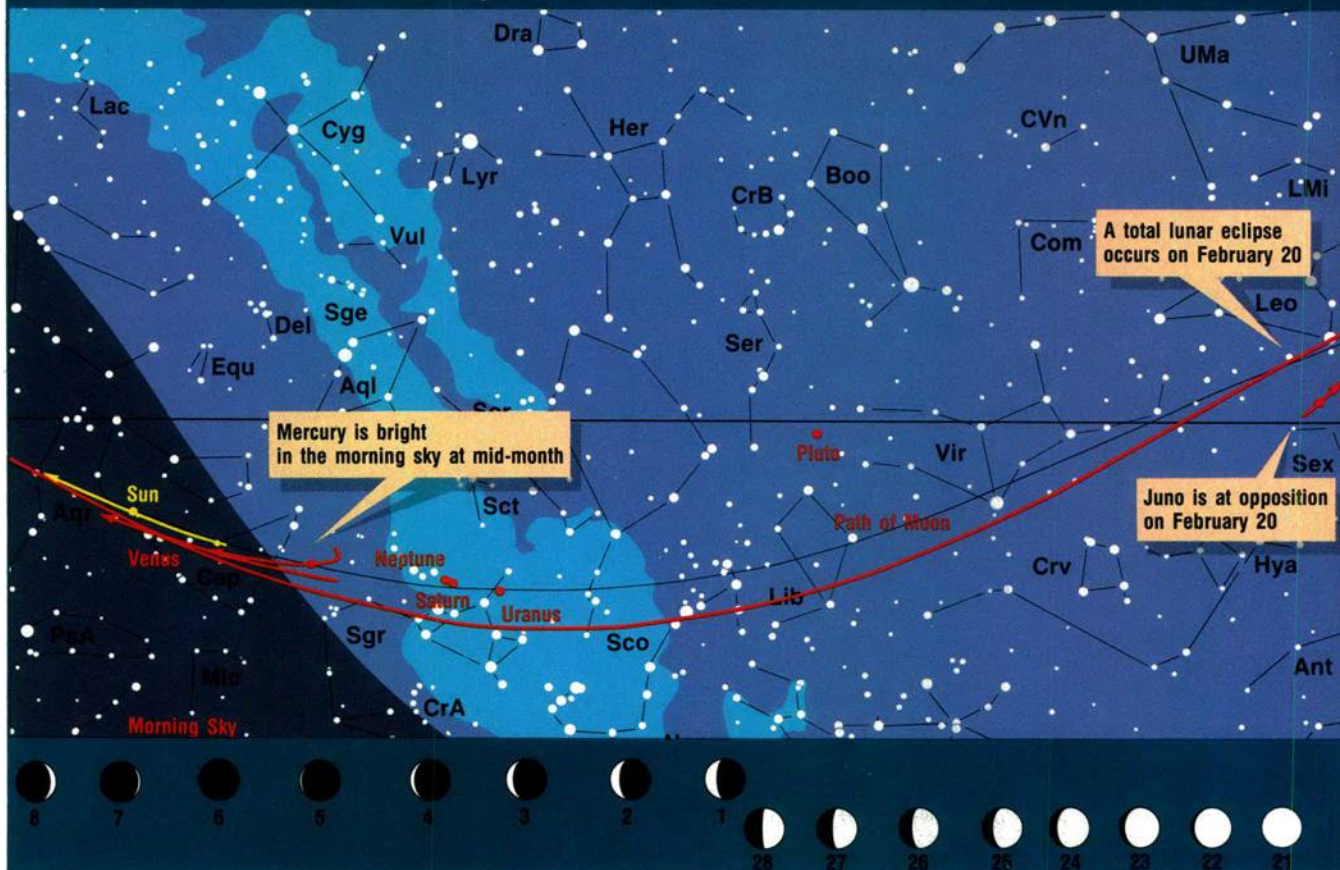
COORDINATES FOR IRIS

Date	R.A. (2000)	Dec.
Jan. 31	9h33.0m	5°58'
Feb. 10	9h22.4m	6°34'
Feb. 20	9h12.5m	7°18'
Mar. 2	9h04.4m	8°02'
Mar. 12	8h59.0m	8°42'
Mar. 22	8h56.6m	9°13'
Apr. 1	8h57.2m	9°34'

FOLLOW ASTEROID 7 IRIS as it moves north of the head of Hydra during February and March. The minor planet is brightest at opposition, which occurs on February 9. (Positions are given for 0 UT.)

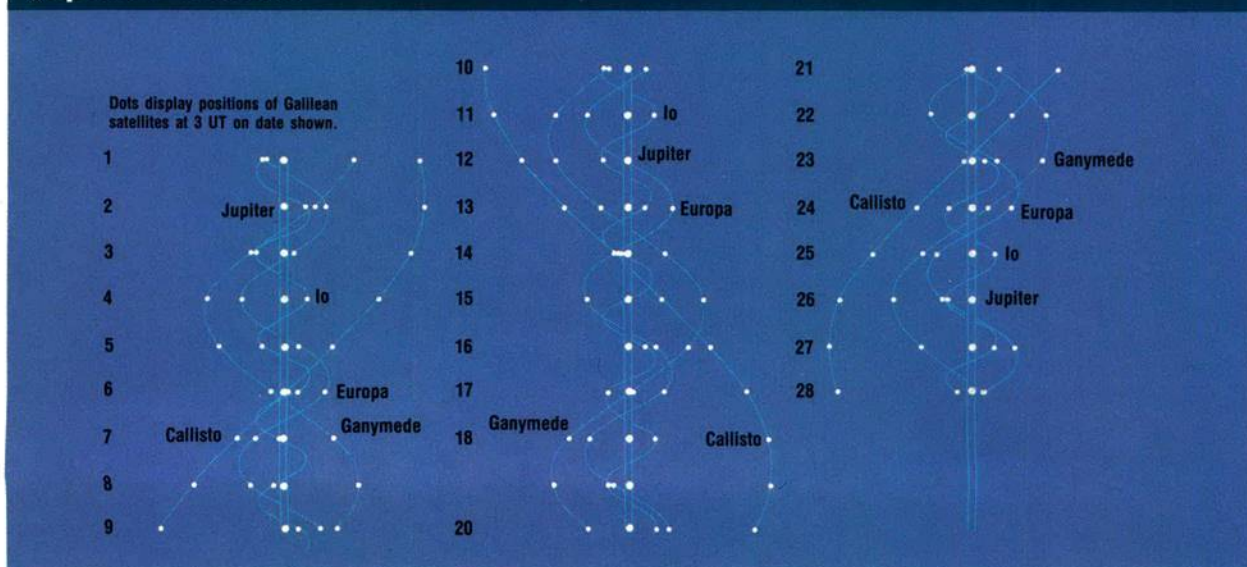


The Solar System February 1989



Planet	MERCURY	MERCURY	MERCURY	VENUS	MARS
Date	February 1	February 15	February 28	February 15	February 15
Magnitude	+1.7	+0.1	0.0	-3.9	+0.8
Angular Size	9.70"	7.36"	6.07"	10.0"	6.7"
Illumination	14%	53%	72%	98%	89%
Distance (AU) from Earth	0.694	0.913	1.108	1.663	1.403
Distance (AU) from Sun	0.362	0.435	0.466	0.728	1.555
Right Ascension (2000.0)	19h56.4m	20h09.4m	21h10.0m	21h08.1m	2h50.7m
Declination (2000.0)	-17°19'	-19°15'	-17°32'	-17°29'	17°36'

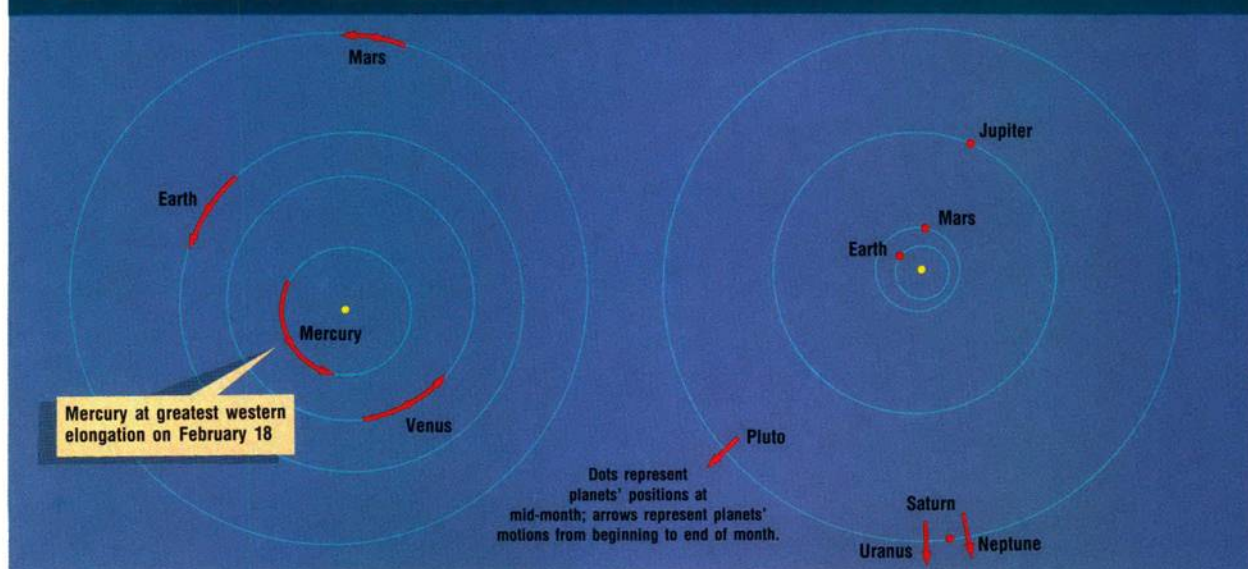
Jupiter's Moons





JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15
-2.4	+0.6	+5.7	+8.0	+13.7
39.9"	15.5"	3.5"	2.2"	0.1"
99%	100%	100%	100%	100%
4.931	10.706	19.913	30.911	29.459
5.045	10.043	19.323	30.218	29.658
3h40.9m	18h46.1m	18h18.8m	18h50.3m	15h09.9m
18°53'	-22°20'	-23°36'	-22°02'	-1°08'

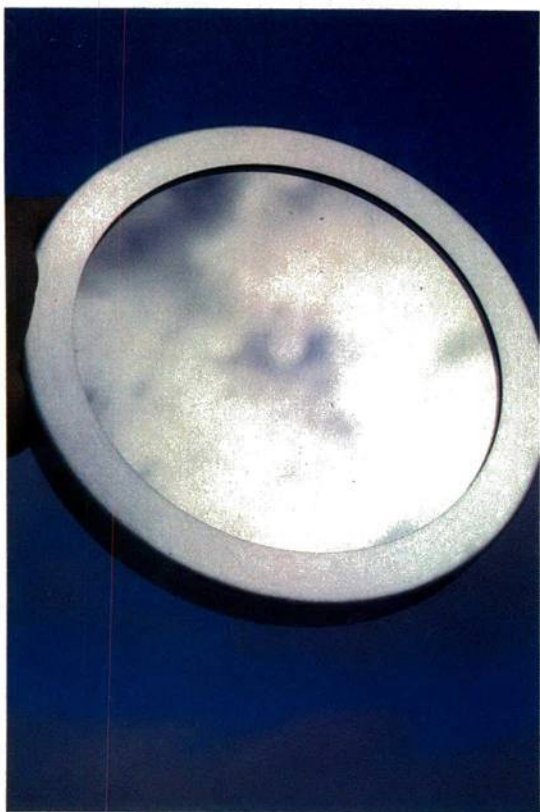
The Planets in Their Orbits



Equipped for Safe Solar Viewing

Use full-aperture solar filters or solar projection to get safe, effective views of the Sun.

by Richard Hill



THIS OVER-THE-APERTURE FILTER from Thousand Oaks Optical provides a safe way to observe the Sun.



A COOL BLUE SUN (above) is produced with Roger Tuthill's "Solar Skreen" filter. A #16 Wratten filter coupled with Tuthill's filter yields a yellow Sun (below). Photos taken by James Felbab.



If the predictions hold up, the solar cycle presently building to its 1991 peak will be the most active ever observed. This means the Sun will present an ever-changing display of huge, complex sunspots, bright flares, and prominent faculae. Furthermore, those details will be easily visible in small telescopes.

These exciting prospects will spur a lot of people either to buy or borrow a telescope to look at the Sun or to adapt their existing instrument for solar observing. Undoubtedly many questions will be asked about solar observing: What can I do to make my night telescope a good solar telescope? Is solar projection a viable alternative to using solar filters? What are the costs? How can I observe safely?

To get started, you'll need three essential components: the optimal telescope aperture, the proper filtration method, and some kind of shading for the instrument.

The telescope's aperture should be at least 1 inch but should not be greater than 6 inches. The upper limit is set by a general guideline of solar astronomy stated in R. J. Bray and R. E. Loughhead's book *Sunspots* (Dover, 1979): daytime seeing of 1 arcsecond is only experienced about 1 percent of the time at the best sites. This sets an upper aperture limit of about 4.5 inches, for which the theoretical resolution is 1 arcsecond. This is not to say a 6-inch telescope is too big, only that 6-inch and larger sizes may from time to time produce a Sun that shimmers to the point of distraction, an effect known as "boiling."

Atmospheric convective cells passing in front of the telescope's aperture can make the Sun's image boil to the extent that exact focus is impossible to achieve. Observers with telescopes 6 inches and larger can reduce this effect by stopping down the instrument's aperture to a focal ratio of

about $f/20$ with a stop-down mask. For example, an 8-inch $f/10$ becomes an $f/20$ scope when stopped down to 4 inches. (See "Sharpen Images with a Cardboard Mask" by M. Leon Knott on page 84.)

Stopping down the telescope's aperture increases the depth of focus and hence the sharpness of the image. This is especially important when photographing the whole solar disk with Schmidt-Cassegrains and their curved focal planes. A full-aperture photograph taken through one of these telescopes shows either the edge or the center of the Sun in sharp focus but never both. By stopping down the aperture to $f/20$, you do not sacrifice resolution (1-arcsecond resolution is achieved only 1 percent of the time), yet the whole disk is in sharp focus. When stopping down, don't worry about the edge obstruction of the secondary because this has little effect on the image.

Project, Filter, or Reduce?

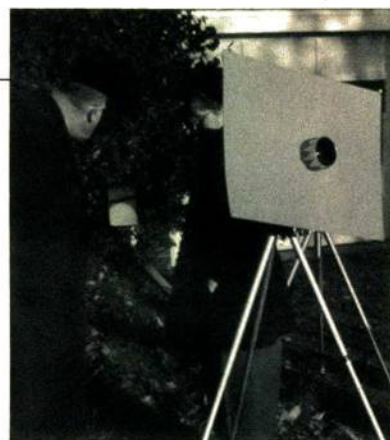
There are three ways to adapt a telescope for solar observing: projecting the image through the instrument on to a screen, filtering the light before it enters the instrument, and reducing the light after it is collected by the primary lens or mirror at some distance from the focal plane.

Projection is the safest method for the observer. When projection is properly done, the eye is never placed in jeopardy. The observer allows unfiltered sunlight to pass through the telescope and an eyepiece and the image is focused on to a screen behind the eyepiece. Disk sizes obtained with this method range from 4 inches to 4 feet. Too small a disk will fail to reveal the smallest sunspots and too large a disk will yield too faint an image.

The projection screen should be shaded so the Sun can be clearly seen. A disk size that seems to be a good compromise between the above parameters is three times the tele-



NEWTONIAN REFLECTORS make good solar scopes with Mylar filters like this one manufactured by Roger W. Tuthill, Inc.



SOLAR PROJECTION is effective when the screen and the telescope are shaded.

scope's aperture. So for a 4-inch scope you would want a 12-inch-diameter disk.

Telescopes with corrector plates (e.g. SCTs) are not recommended for projecting the Sun. The plates tend to lie too close to the prime focus of the primary mirror, where light is concentrated. Should the Sun's image stray from the secondary, it could result in a melted plastic secondary baffling or a broken corrector. Also, when showing a projected image to a throng of enthusiastic spectators, be sure that no one tries to look into the eyepiece. This seems to be something small children instinctively try to do.

There are myriad prefilters, also known as over-the-aperture filters, available that will convert the commercially manufactured telescope into a solar telescope. Like telescopes, not all prefilters are created equal; some are marginally better than others, and a few are just barely passable for optical purposes. If possible, try out a filter first or talk to someone who owns the kind of filter you are thinking of buying.

There are two categories of prefilters: metal on glass and aluminum on Mylar. With either type there are some common things to look for. First, no filter should impede a telescope's ability to come to a clean, sharp focus. If a filter introduces astigmatism, the most common problem with glass filters, do not buy it. If you have already bought it, return it to the manufacturer and either ask for another filter or your money back.

Second, the sky just beyond the edge of the Sun's disk should be dark, not a haze of light. This problem often shows up in inferior-quality Mylar filters. While any filter will degrade a telescope's performance to some degree, no filter should do so by more than a factor of two in resolution. A 6-inch aperture should consistently show granulation in good seeing with

a magnification of 100x or more.

Also, avoid filters that have more than just a few pinholes in the coatings; these filters may be defective. While the filters can be fitted with a stop-down mask, each mask will scatter and diffract light, which causes further degradation of the image.

Although plane-parallel glass filters with a nickel-chrome coating may be the nicest filters to own, a Mylar filter (aluminum coat) can be used effectively for solar observing. Because there are a lot of poor-quality Mylar filters on the market, Mylar has gotten a lot of bad press over the years. However, there are some excellent brands.

Because of the vagaries of daytime seeing, you would do well to stop down your telescope to $f/20$ if you use either glass or Mylar filters. This will result in a more pleasing image that will tend to boil less.

There are two dangers to watch out for with prefilters. First, make sure the prefilters are not held too tightly in their cells. This can cause cracking in glass filters and stretching in the Mylar filters as they heat up. Second and most important, when showing the Sun to friends and especially to children, be sure that the wind or little fingers cannot remove the filter. Both will try to do so!

The last light-reduction method of solar observing was developed by the father of modern observing, Sir William Herschel. The method employs a device called, appropriately enough, the Herschel Wedge. A Herschel Wedge is a thin, narrow-angle prism that replaces the secondary mirror in a Newtonian telescope or the prism for compound and refractor telescopes. The wedge reflects about 5 percent of the Sun's light into the eyepiece and passes the rest through the prism. Five percent of the Sun's light is still quite strong, but neutral density filters that transmit 0.01 or 0.001 per-

cent of the light can be coupled to the eyepiece to greatly reduce the Sun's intensity.

However, with full-intensity sunlight passing through the telescope, you will have to deal with the image degradation that results from heat waves (especially in Newtonian reflectors), and you will need to periodically cover the aperture to prevent the optics from getting overheated.

The wedge should be kept well away from the focal plane of the telescope, especially if the wedge is coated to pass more light. This will also reduce any heating problems that might cause the wedge's surface figure to distort. Although this is an excellent light-reduction system, Herschel Wedges are hard to find these days because no optical shop manufactures them. You might try your luck at star party swap meets and the classified ads in *ASTRONOMY*.

No matter which solar observing method you use, the amount of detail you see will depend a great deal upon the Sun's position in the sky. As a general rule, the higher the Sun is in the sky, the better the seeing. The best seeing most often occurs in the few hours before noon. But the Sun can be low in the sky then, especially for observers far from the equator. For example, for observers with latitudes of 36.5° , the Sun will not even get 30° above the horizon at noon on the shortest day of the year. As a result, atmospheric refraction becomes a significant hindrance when you're trying to get good resolution out of a telescope while observing the Sun at such a low altitude. At 40° altitude, atmospheric refraction limits resolution to 1 arcsecond at best. Below this it worsens rapidly: at 30° it's 2 seconds and at 20° it's 4 seconds.

Shading Your Telescope

One thing many observers fail to do is protect their telescope from the Sun's heat. The heat can cause tube



SUNSPOTS AND GRANULATION are some of the features you can see in any scope rigged for solar viewing. Photo by J. Metcalfe with a Thousand Oaks photographic filter.

currents and distort the optics, which results in an unsharp image. Sunlight falling on part of the telescope tube can cause flexure as that side expands and throw carefully aligned optics out of alignment. Plastic tubes (e.g. PVC) will sag, producing a similar effect. Shade also reduces the harsh glare of the Sun, which can infiltrate the eye and lower contrast, especially if you are projecting the Sun.

A large cardboard or foamboard flange mounted at the upper end of the telescope tube will shade most of the instrument and the observer (although you may have to rebalance your telescope). However you rig it, the screen must come between the telescope's aperture and the focuser.

In a similar vein, don't let heat build up on the optical components when projecting the Sun's image. When you're not directly observing, cover the telescope's aperture. This is most critical with reflectors in which the figures of the mirrors can be distorted. If you are using a refractor, bear in mind that heated optics will change your instrument's focal length. If heating occurs too rapidly, like at the focal plane, glass in eyepieces can crack or break, cemented lenses can separate, and those nice expensive coatings can dissolve into a hazy film on the lenses. Use only inexpensive uncemented eyepieces to avoid any damage from the heat.

The Best Part: It's Cheap!

You can spend vast sums of money converting a nighttime telescope to one for solar observing, but this is not necessary. The least-expensive method to begin with is projection. It costs virtually nothing, especially if you are resourceful enough to construct your own projection screen.

Two of the biggest suppliers of full-aperture filters are Roger W. Tuthill, Inc., and Thousand Oaks Optical. For \$49, Tuthill will sell you enough Mylar to make your own full-aperture

filter for a 6-inch telescope. For \$75, you can buy the Mylar mounted in an aluminum cell. Tuthill's filters are probably the least-expensive route for observers with telescopes that cannot be used for projection. The filters render the Sun a cool blue color. To make the Sun appear a more natural yellow for color photography, use a Wratten 15 or 16 filter.

Glass filters from Thousand Oaks Optical come in three different types and thus three different price ranges. The basic filter, type 1, is coated with a nickel-chromium alloy and mounted in an aluminum cell and costs about \$74 for a 6-inch aperture. Type 2 has a stainless steel coat to resist scratching and costs \$99. The type 3 filter has a neutral-density coating and is meant to be used by astrophotographers, who need a stronger solar image (it's not meant for visual use). The price is \$129. These filters render the Sun a yellow-orange color.

Observe the Sun Safely

Safe solar observing cannot be stressed enough. Solar observing is the only inherently hazardous form of observing amateurs can do. It can be enjoyable and exciting if done carefully, but one careless moment can result in permanent blindness. By following a few guidelines, you can prevent injury to both your telescope and yourself.

First, *never* look at the Sun in a telescope filtered with an unknown material. You could be damaging your eye and not know it. The retina has no nerves capable of sensing pain, and though too much light in the visual spectrum causes discomfort almost immediately, infrared and ultraviolet light causes little discomfort as it destroys the eye, contrary to popular myth. This means there will be little or no warning that damage is being done until it is too late. Some unacceptable filters are photographic neutral-density filters, smoked glass, and

developed color transparency film.

Second, be sure filters are securely fastened to the telescope. If a filter breaks or the wind blows a filter off the telescope while you are looking into the eyepiece, the eye will be damaged in only one thousandth of a second. It takes the average person a tenth to two tenths of a second to respond to a stimulus, even a painful one. The result would be central blindness, a particularly gruesome reverse-tunnel blindness in which central vision (if not total vision from damage to the optic nerve) is lost but peripheral (averted) vision is still working.

Third, under no circumstances should you observe through a telescope that shows any light on a card held up to the exit pupil of the eyepiece. This is entirely too much visual light, not to mention infrared and ultraviolet light. If you are not sure a filter is safe, don't use it.

Fourth, never use screw-on or over-the-eyepiece solar filters. These so-called "Sun" filters are very dangerous and should be discarded or, better, destroyed. If they screw on to the entrance end of the eyepiece, they are quite close to the prime focus of the telescope lens or mirror and hence close to the concentrated light. The filter, absorbing some 99.999 percent of the light, heats up so fast that there is a danger of the glass cracking.

A worse situation can occur with the filter placed at the exit end of the eyepiece. Here the light is also concentrated, especially at low magnifications, and the eye is only a millimeter or so from the filter. If the filter breaks this close to the eye — and it will break eventually — small slivers of glass as well as unfiltered sunlight will get into the eye. Only in the exceptional case, where a special solar telescope is made to substantially reduce the light before it enters the eyepiece, should an eyepiece filter even be considered.

The Sun is the most active object available to the amateur astronomer for study. It is an exciting field of endeavor but must be approached with caution. There are a number of safe, easily accomplished methods for observing, so you need not resort to any risky, unknown filters. Go out, observe, and enjoy what is apparently going to be one of the most active solar cycles in history. But don't gamble with your vision. □

Richard Hill is the general recorder of the solar section for the Association of Lunar and Planetary Observers. He lives in Tucson, Arizona.

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- 7) Telecompressor System\$69
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Eclipse Prospects for the 1990s

Start making your travel plans with this weather guide to the next eight total solar eclipses.

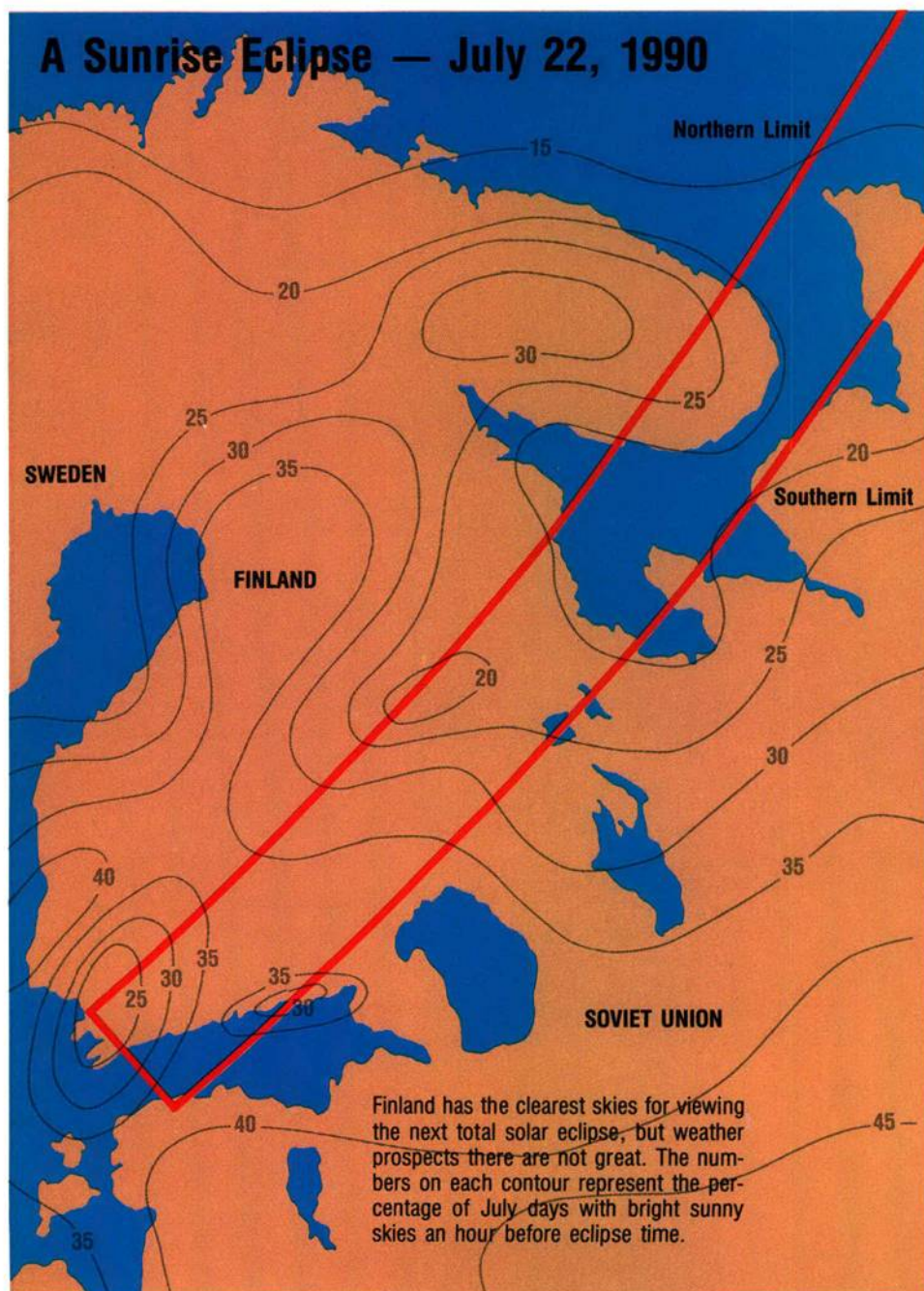
by Jay Anderson

Eight total solar eclipses are left in this century: eight more opportunities to marvel at the Sun and its coronal structure, eight more reasons to travel and see the world, eight more times for eclipse chasers to share their experiences with others. Eight memorable eclipses — weather permitting.

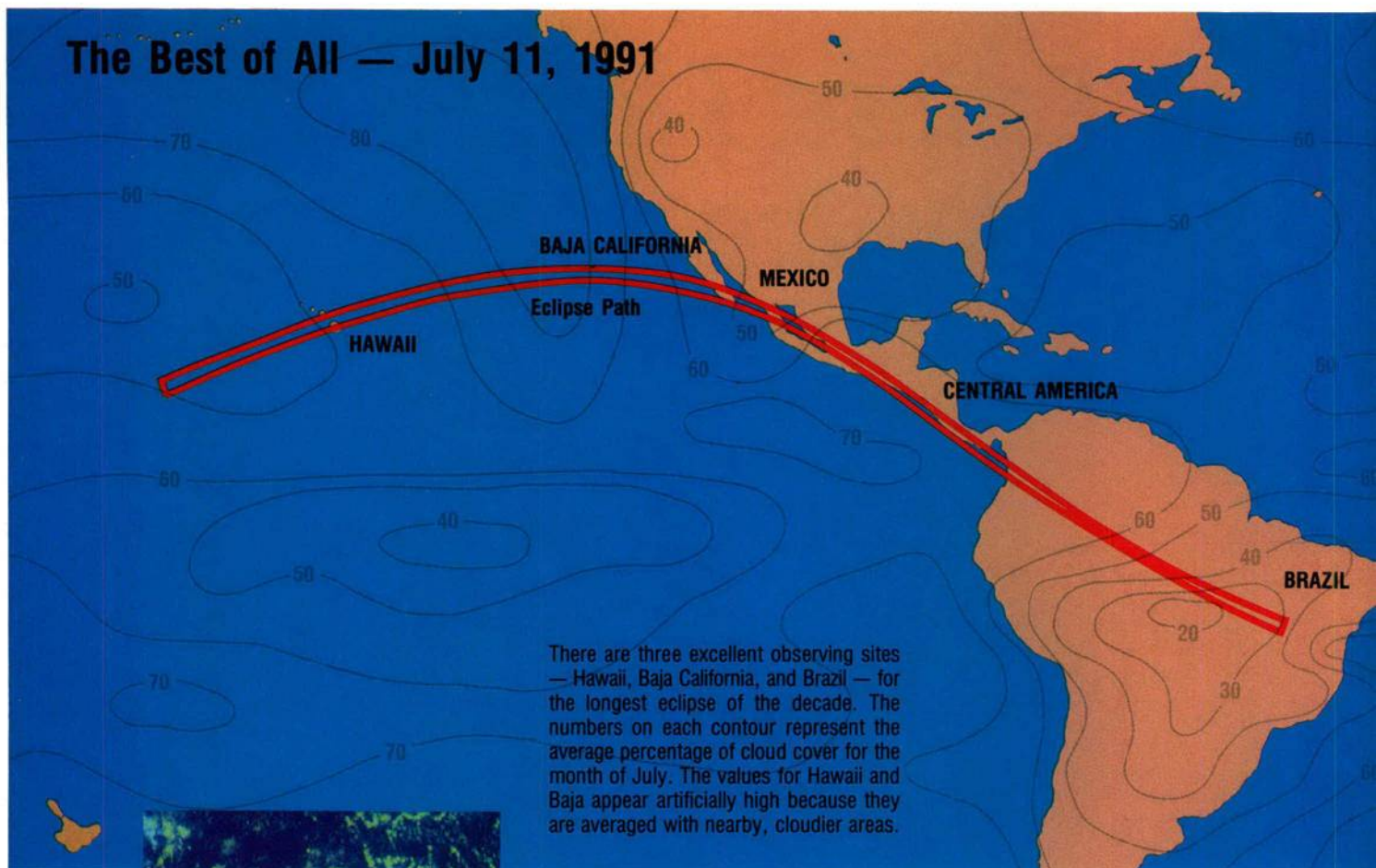
Fortunately when you're choosing a good eclipse site, weather is one factor at least partially under your control. Although we can't change the weather at a specific site, we can usually pick a site where the probability of clear skies is reasonably high. Combined with the other major factors affecting the quality of an eclipse site — the site's accessibility and local circumstances such as the duration of totality and the altitude of the Sun in the sky — weather prospects can help narrow the potential choices to the few best.

No one can guarantee clear weather on any given day, particularly on a day years in the future. However, weather patterns in most of the world are remarkably consistent from year to year. By examining the weather patterns that have brought clear and cloudy weather conditions in the past, we can get a good idea of how likely those conditions are in the future. And by analyzing each eclipse for the next decade, we can find the locations that are most likely to be clear on eclipse day and that provide good local eclipse circumstances.

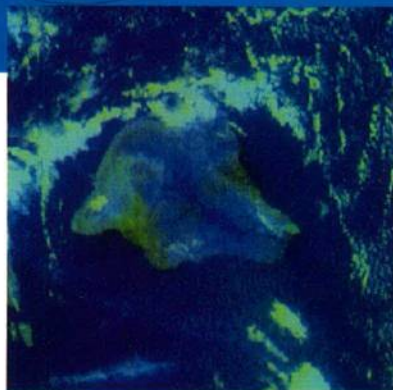
Statistics of the global cloud cover for each month of the year have been compiled from satellite images gathered between 1971 and 1980 by the Soviet Hydro-Meteorological Scientific Research Institute and the University of Leningrad. The researchers first divided the world into regions 10° in longitude by 5° in latitude on a side, and then they estimated the amount of cloud cover present in each region four times every day. The "mean



The Best of All — July 11, 1991



There are three excellent observing sites — Hawaii, Baja California, and Brazil — for the longest eclipse of the decade. The numbers on each contour represent the average percentage of cloud cover for the month of July. The values for Hawaii and Baja appear artificially high because they are averaged with nearby, cloudier areas.



SATELLITE IMAGES reveal the excellent weather prospects for the 1991 eclipse in Hawaii (left) and Baja California (opposite page). Both images were taken on July 11, 1988, and show weather patterns typical of that time of year.

cloud cover" they derived is the average of all these measurements during a month.

These results were then combined with eclipse tracks provided by Fred Espenak of NASA's Goddard Space Flight Center to get an indication of weather prospects for each eclipse remaining until the year 2000. Because the mean cloud-cover numbers are based on relatively coarse latitude and longitude grids, they cannot reveal the finer details of the world's cloud structure. They do, however, provide an excellent basis for planning future eclipse expeditions.

Eclipse in the North

The next total solar eclipse passes through northern Eurasia on July 22, 1990. The Moon's umbral shadow

first touches Earth near Helsinki, Finland, and then heads northeastward to skip along the Soviet Union's Arctic coast. Angling southeast over eastern Siberia, the shadow leaves the Asian mainland and sweeps across the Aleutian Islands before departing from Earth in the eastern Pacific.

The weather prospects for this eclipse are poor: the mean cloud-cover figures average 50 to 60 percent across the European and Asian portion of the track and 70 to 80 percent over the Aleutians. The cold Arctic seas are noted for persistent low clouds and fog during the summer months, while inland areas lie in the path of the migrating low-pressure systems that characterize the Northern Hemisphere climate. High-pressure systems, which bring better prospects for sunny skies, are not common, and the frequency of days with scattered clouds is only 10 to 20 percent.

Finland has the most favorable weather prospects along the eclipse track. Finland is also a good site because access is easy. Alas, the better

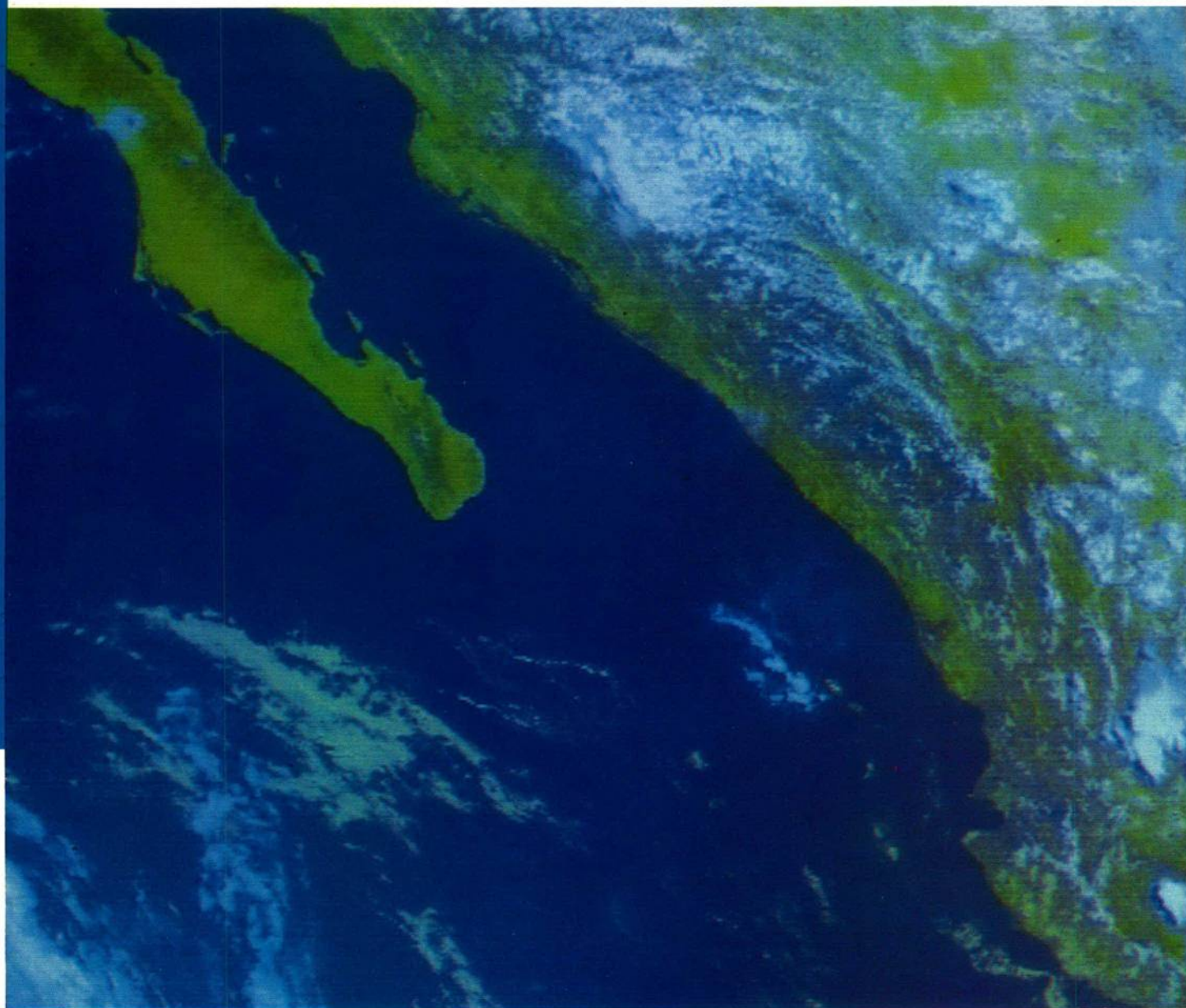
weather prospects come with a severe penalty: the eclipse occurs less than 5° above the horizon and clouds tend to appear thicker in that direction because of perspective effects. The solar elevation increases to 8° on the southern shores of the White Sea, but there the mean cloud cover is significantly higher than it is over Finland.

In eastern Siberia where the eclipse attains its highest altitude (40°) and longest duration (two minutes and thirty-six seconds) in the mountains north of the Kamchatka Peninsula, the frequency of clear skies is one half that in Finland. Worst of all, observations at Adak in the Aleutians show a miserable 99 percent cloud cover in July.

The Best of the Decade

Mark July 11, 1991, on your calendar. That's the date of the best eclipse left in this century — the longest total eclipse until 2132 and one blessed with two excellent and accessible observing sites.

The Moon's shadow engulfs the big island of Hawaii at 7:30 a.m. local



time. The center line of the eclipse shadow passes a few miles south of the telescope-clad peak of Mauna Kea, where the 21°-high Sun is masked for over four minutes. An hour and a quarter later (11:45 local time) the umbra touches land again at the southern end of Mexico's Baja Peninsula. Totality lasts just under seven minutes there, which is nearly the maximum possible. After passing through most of the countries of Central America, the shadow crosses the mountain jungles of Colombia before ending in the central plains of Brazil.

Weather statistics suggest three excellent sites for viewing this eclipse: the volcanic peaks of Hawaii, Baja California, and Brazil. Observers should find the first two sites, in par-

ticular, relatively accessible.

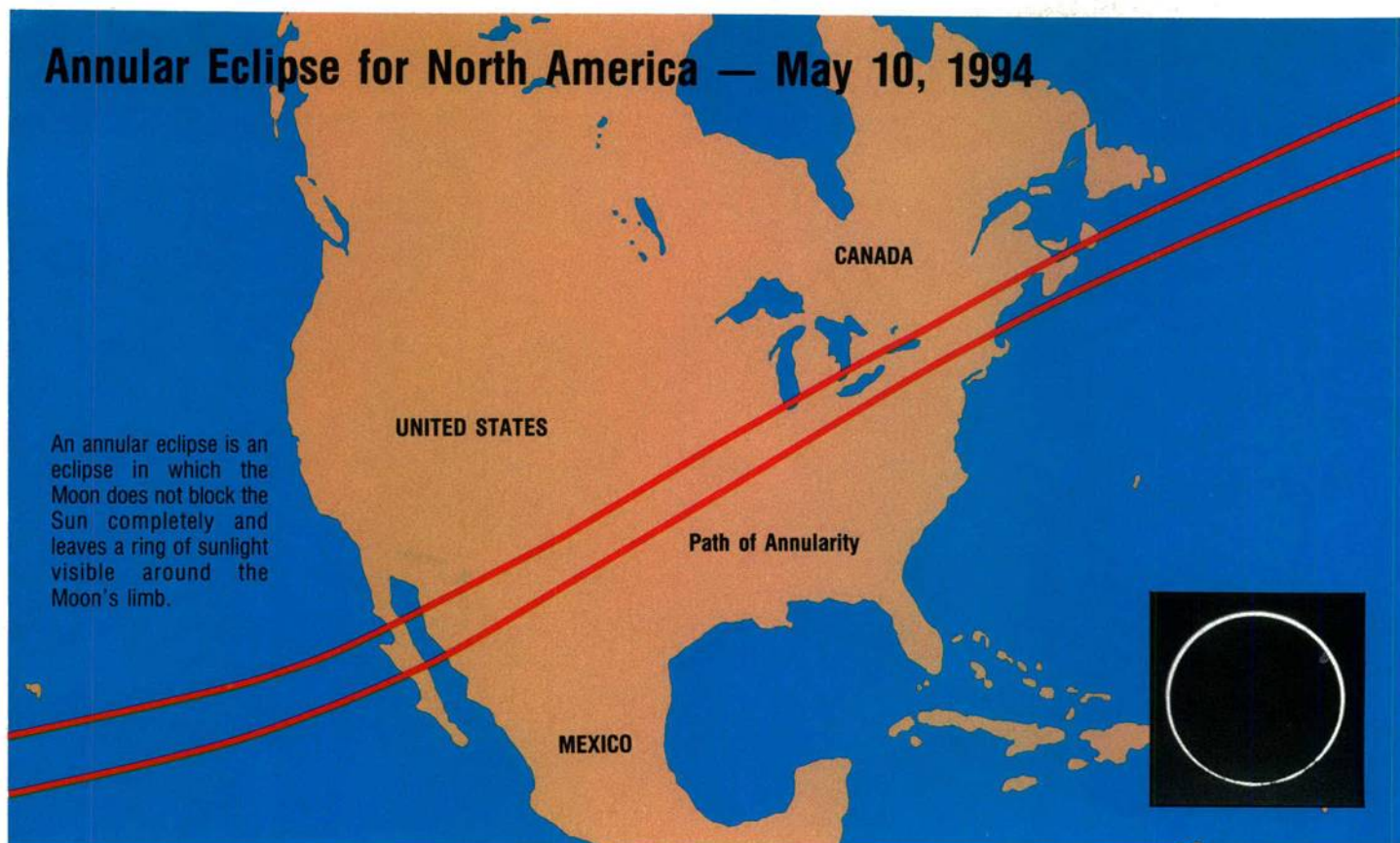
During July Hawaii is influenced by the steady northeast trade winds, which carry moist Pacific air onto the windward slopes of the volcanoes. This moist flow is topped by a temperature inversion that usually occurs at 6,000 to 7,000 feet above sea level. Dry air above the inversion brings the clear skies valued by the astronomers who use the island peaks.

At lower elevations the cloud cover on Hawaii varies greatly, influenced mostly by the flow of winds around the rising terrain. As long as the trade winds blow — 95 percent of the time during July — the windward slopes of the island tend to be cloudy. Observers who place themselves at higher levels will escape much of the cloudy

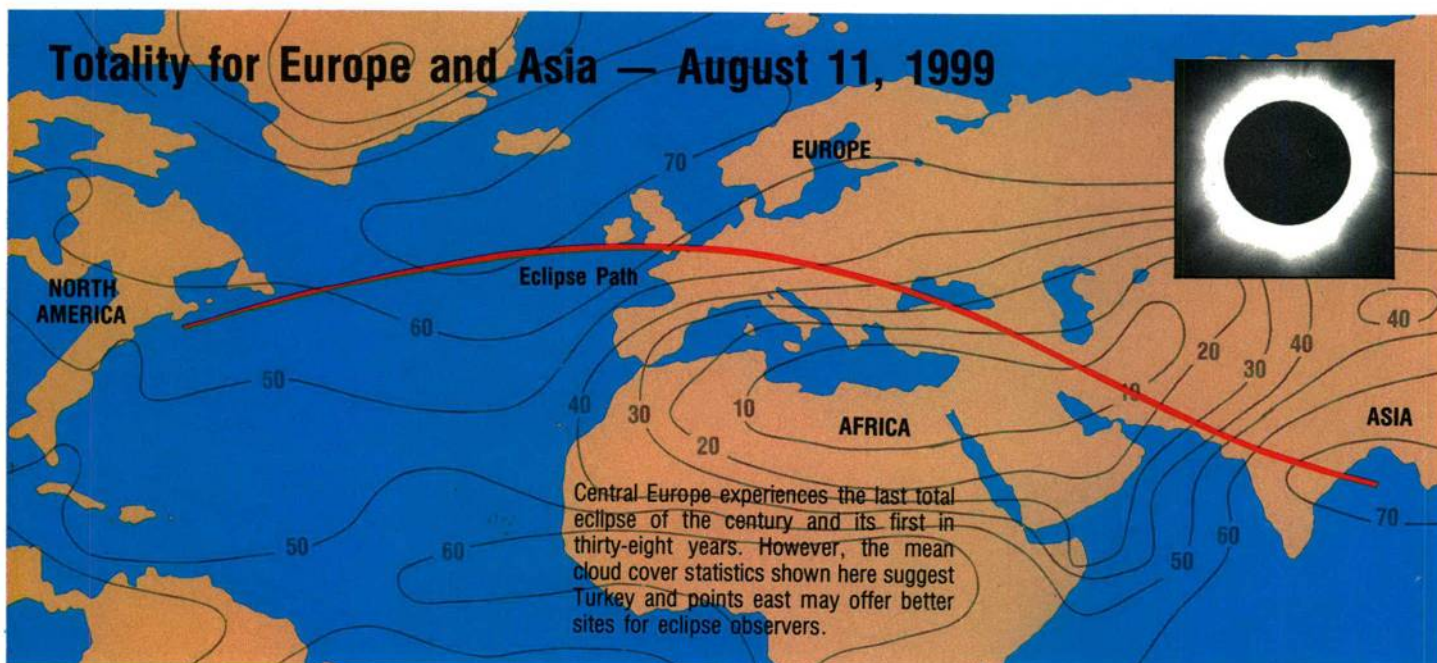
cloak, but to be safe, you should find an eclipse site at least a little above the inversion. (See page 59 in the December 1987 issue for a picture of low-level cloudiness as seen from Mauna Kea.)

Higher clouds, carried over the islands from equatorial regions by the subtropical jet stream, are also an occasional unwelcome sight above the peaks of Hawaii. Though high-level clouds tend to be thinner because the cold air at high levels cannot carry as much moisture as lower, warmer air, these clouds probably represent the greatest threat to eclipse chasers located on the volcanic slopes. Over the past five years high-level clouds thick enough to interfere substantially with the eclipse

Annular Eclipse for North America — May 10, 1994



Totality for Europe and Asia — August 11, 1999



have occurred an average of three times during July.

An excellent site, well above the inversion, is at Hale Pohaku, over 9,000 feet above sea level on the road toward Mauna Kea's summit. At higher altitudes, though, the unacclimated eclipse chaser may suffer the mind-fuzzing effects of oxygen deprivation and could risk more serious medical problems. In any case,

the summit road above Hale Pohaku will be closed to the public on eclipse day. Another good spot should be at Puhakuloa, located 6,000 feet up on the west side of the saddle linking Mauna Loa and Mauna Kea.

Despite the long and dusty road from San Diego, Baja California will probably be the most popular site for viewing the eclipse. Cruise ships will be able to tie up at San Lucas on

Baja's southern tip, and ferry service is available from mainland Mexico. Located near the point of greatest eclipse with the Sun almost overhead, Baja has many attractions for the shadow seeker. And, best of all, the weather prospects are excellent.

During July the rainy season is just about at its peak over Central America, but the Baja remains remarkably dry and usually sunny. A typical day

in Baja begins with patchy low clouds and fog along the western coast of the peninsula and thin high-level cirrus floating above the eclipse site. As morning progresses, the cirrus clouds gradually evaporate, and midday is normally the least cloudy time of day. Afternoon skies are clear for the most part, but during the evening and night high clouds move in from the east, cast up by thundershowers over the Mexican mainland and carried to the peninsula by the prevailing winds.

When evening thunderstorms are particularly active on the west coast of Mexico, the cloud cover that moves onto Baja the next morning is thicker and more persistent than usual. This thicker cloud cover represents the biggest threat to eclipse chasers on Baja and occurs an average of five days in July. It is most likely to occur if an upper-atmosphere high-pressure system lingers over northern Mexico, which strengthens the winds from the east.

Those who prefer observing the eclipse from aboard ship will find that the skies west of Baja California are occasionally obscured by low clouds and fog. A location on the center line toward the mainland coast should have better prospects.

Through Central America and across northern Colombia the eclipse track moves toward the Intertropical Convergence Zone (ICZ), which is particularly prominent in this part of the globe. The ICZ is an area of heavy cloudiness and precipitation, brought on by the convergence of winds from the Northern and Southern Hemispheres. Organized thunderstorm clusters are frequent across Panama and on the Pacific side of the Andes Mountains of Colombia but less common in the deep mountain valleys near Bogota. The eclipse comes to an end in the Brazilian plains in one of the least cloudy areas along the track. The eclipse will be low in the sky and thus will require a clear horizon, but July is the sunniest month of the year and the frequency of completely clear skies is as high as 60 percent.

Out at Sea

The center line of the June 30, 1992, eclipse never touches land: it moves across the Atlantic from the mouth of the Rio de la Plata east of Buenos Aires to its terminus southeast of Cape Town. (However, Montevideo, the capital of Uruguay, has a brief period of totality at sunrise.) It's unfortunate that the eclipse follows a watery path because this eclipse is the second longest of the decade — over five minutes in the mid-Atlantic.

Even though much of the eclipse track moves through the subtropical

high-pressure system that dominates these latitudes, cloud cover is heavy, especially on the African side of the Atlantic. Most of these clouds form from the moisture trapped under a low-level inversion, a situation similar to that near Hawaii for the 1991 eclipse. Along the South American coast, low-pressure systems spawned in the mouth of the Rio de la Plata and the South Pacific are most responsible for the cloudiness.

Most eclipse chasers will view this eclipse from aboard ship, where mobility will substantially increase the likelihood of seeing the event. As the shadow's track moves closer to the subtropical high, winds will decrease steadily and waves will become smaller. However, cloud cover increases along the eclipse track, so ongoing meteorological information will be important for finding a hole in the clouds.

Return to South America

The total solar eclipse on November 3, 1994, again favors South America and the south Atlantic. Fortunately this eclipse offers much more land access than the one in 1992. The eclipse begins in the Pacific Ocean south of the Galapagos Islands; the shadow makes first landfall on the coast of Peru near Arequipa. The center line then crosses Chile, Bolivia, Paraguay, and southern Brazil before heading out to sea once again. Maximum duration is just under four-and-a-half minutes in the Atlantic east of Uruguay, but totality lasts over four minutes on the east coast of Brazil north of Porto Alegre.

Although the oceanic portions of this eclipse are across the subtropical highs, the interior of South America is ruled by a large, low-pressure system. This pattern brings persistent low clouds along the Peruvian coast and drier but unstable weather over Brazil and Paraguay. Inland Peru, away from the ocean cloudiness, is possibly the best eclipse site. At Arequipa, skies are mainly sunny at the time of eclipse an average of twenty-one days in November.

The low-pressure system over Brazil brings a high frequency of showers and thundershowers, but the eclipse occurs near 10 a.m. local time when the convective clouds are just beginning to develop. The cooling associated with the approach of the lunar shadow should dissipate much of the cloud cover.

A Quick Pass through Asia

The shortest total eclipse of the decade begins over Iran on October 24, 1995. It then crosses Afghanistan and the Indian subcontinent before moving into southeast Asia and the

western equatorial Pacific. At its maximum the eclipse lasts a little more than two minutes over the waters of the South China Sea, and in the best weather area along the India-Pakistan border it lasts only three quarters of a minute. Mean cloud cover in October dips to less than 10 percent over the Great Indian Desert west of Delhi, which is the result of a huge high-pressure system sitting atop the Himalayas.

October in India is a month of transition, when the cloudy and wet southeast monsoon is giving way to sunny and dry northwesterlies. Calcutta, on the center line, has good weather prospects with a mean cloud cover of 30 to 40 percent. It should be a first-class site, because the eclipse will last thirty seconds longer than in regions over the deserts and the Sun will be twice as high in the sky. Weather forecasts in the days preceding the eclipse and accurate information on the state of the monsoon in the fall of 1995 will allow observers to make short-range plans and slightly alter their eclipse site.

A Cold Eclipse

A brief eclipse on March 9, 1997, follows an unusual track that sweeps from Mongolia across eastern Siberia almost to the North Pole. Weather prospects for this eclipse are excellent, largely because Siberia is still cold enough in March that the air is unable to hold much moisture!

The early portion of the eclipse track across Mongolia and southern Siberia is relatively cloudy with a mean cloud cover of 40 to 50 percent. The shadow line passes a short distance north of the capital of Mongolia, Ulan Bator. East of Lake Baikal the center line crosses the Trans-Siberian railway, so access is also available to those wishing to travel northward from Vladivostok or eastward from Europe.

Farther north, close to the area of maximum duration (just under three minutes) in the remote mountains west of the Sea of Okhotsk, the only readily accessible site is on the highway between Magadan on the Pacific coast and Yakutsk on the Lena River. The advantage of a lower mean cloud cover (20 to 30 percent) may not be enough to attract any but the most intrepid travelers. March is not springtime in Siberia: the average daily high this far north is -21°C (-6°F) and the average daily low is a bone-chilling -40°C (-40°F).

South America — Again

Although the February 26, 1998, eclipse occurs mostly over the Pacific and Atlantic oceans, it conveniently crosses land at the center of its path,

TOTAL AND ANNULAR ECLIPSES IN THE 1990S

Date	Annular or Total	UT of Maximum Eclipse	Maximum Eclipse Duration	Maximum Altitude	Where Visible
1/26/90	Annular	18h51m54s	2m04s	18°	Antarctica, South Atlantic
7/22/90	Total	2h36m45s	2m36s	40°	Northern Europe, northern Asia
1/15/91	Annular	23h43m30s	7m49s	74°	Australia, New Zealand
7/11/91	Total	19h06m08s	6m58s	89°	Hawaii, Mexico, Central and South America
1/4/92	Annular	23h14m43s	11m36s	66°	Pacific Ocean
6/30/92	Total	12h23m23s	5m26s	41°	South Atlantic
5/10/94	Annular	17h19m51s	6m09s	66°	North America
11/3/94	Total	13h47m08s	4m28s	69°	South America, South Atlantic
4/29/95	Annular	17h23m15s	6m31s	70°	South Pacific, South America
10/24/95	Total	4h22m31s	2m15s	69°	Southern Asia, Western Pacific
3/9/97	Total	1h53m38s	2m54s	23°	Siberia
2/26/98	Total	17h35m38s	4m13s	76°	Central and South America, Caribbean
8/22/98	Annular	2h14m03s	3m08s	75°	Indonesia, Malaysia, New Guinea
2/16/99	Annular	6h20m23s	1m16s	62°	Indian Ocean, Australia
8/11/99	Total	10h51m14s	2m27s	59°	Central Europe, Asia

close to the point of maximum duration. Totality, though not the center line, first brushes the exotic Galapagos Islands, then heads over the jungles along the Panama-Colombia border, across northern Venezuela, and through the Leeward Islands between Guadeloupe and Montserrat. The central line of the eclipse touches land only in Panama, Colombia, and Venezuela.

During February the ICZ stretches across southern Colombia, bringing showers and thundershowers to the western half of the track. The proportion of sunshine increases steadily through Venezuela and reaches a maximum in the southern Caribbean. The most accessible good weather site on the center line is north of Maracaibo, Venezuela, where the Sun will be covered for three minutes and fifty-five seconds. During February Maracaibo is at the height of its dry season, and eclipse time in the early afternoon is the brightest time of day.

Mean cloud cover is slightly lower over the Caribbean islands because they are closer to the semipermanent Bermuda high. Convective clouds usually build over the islands during the afternoon, but many of these will dissipate between first and second contact. Those who prefer seeing the eclipse from aboard ship should find the lowest seas in the vicinity of the Leeward Islands.

Shadow over Europe

The last total eclipse of the century is also the first for central Europe since 1961. The eclipse begins at sunrise on August 11, 1999, in the western Atlantic off Nova Scotia. First landfall is on the Isles of Scilly and the southwest tip

of Great Britain. Then, after a grand tour of central Europe, the Middle East, Pakistan, and India, the Moon's shadow leaves Earth in the Bay of Bengal — three hours and half a world after its start. Totality is fairly short, only about two-and-a-half minutes at its maximum over Romania.

Weather prospects improve steadily from Britain to Iran and then begin to decline as the eclipse moves into the summer monsoons of India and Pakistan. Iran and Iraq offer the sunniest skies — among the best in the world at this time of year — but the political climate will have to change considerably before either becomes a popular eclipse site.

Because the eclipse is short, sites located near the point of maximum duration are preferable. In view of the relatively poor weather prospects over much of Europe (though excellent weather forecasting and mobility will compensate somewhat), locations in southeast Europe and Turkey present better alternatives. South of the Black Sea the eclipse is only a few seconds shorter than at maximum and the Sun is well up in the sky.

Improving Your Chances

As the statistics show, there are few areas in the world where clear skies can be guaranteed on eclipse day. The mean cloud-cover numbers given for each region are an average of completely cloudy, partly cloudy, and completely clear days, any of which may characterize the moment when the Sun is eclipsed.

To maximize your chances of good weather, monitor weather conditions up to eclipse day. Make sure you get good weather advice — if not from the

local meteorological service then from another agency that has access to weather information over your site and the inclination to help. Weather forecasts can now provide guidance as far as ten days in advance, and accuracy improves as eclipse day approaches.

Several recent eclipses have been ruined by the sudden development of low clouds between first and second contact, notably in Kenya in 1980 and in Mindanao last year. These clouds form when moist layers in the atmosphere cool as the Sun is hidden, which occurs primarily when winds are blowing uphill from lakes or seas. You may be able to avoid these clouds by simply noting the wind direction on eclipse morning and then placing your observing site in the lee of a nearby hill or ridge.

Have a plan of movement for eclipse day. If you're in a group, elect a few people to watch the weather and to advise the group when to move. Pick a site that allows you to move in many directions, especially to higher or lower terrain.

But, above all, have fun. Informal statistics indicate that you will miss about one in every eight eclipses. So enjoy the scenery, the country, and the people. And promise yourself to catch it all again "next time." □

Jay Anderson is a satellite meteorologist at the Pacific Weather Centre in Vancouver, British Columbia. For the past decade he has provided the U.S. Naval Observatory with studies of weather prospects for its eclipse circulars.

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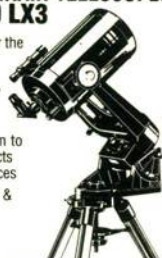
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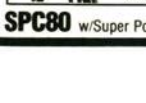
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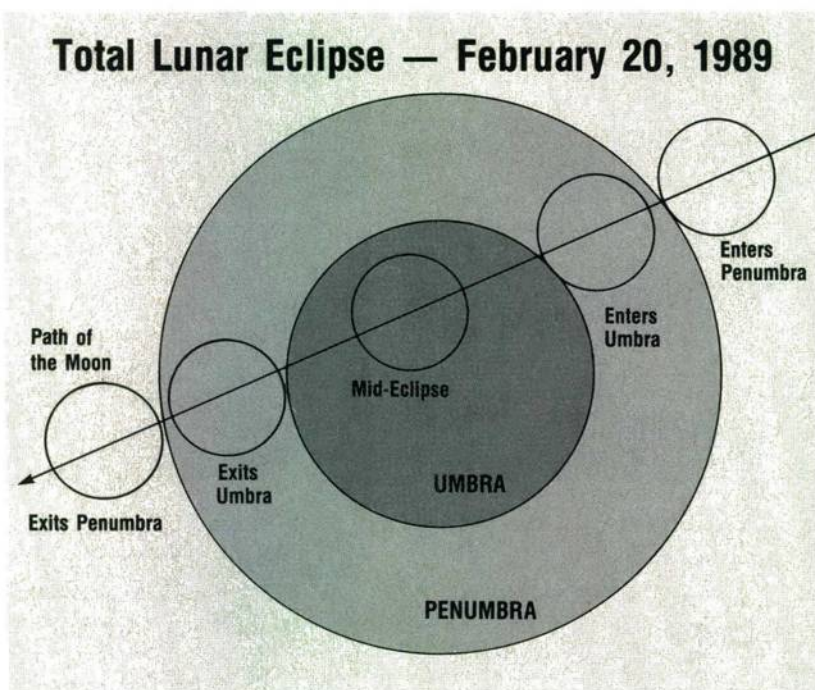
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A PICTURE-PERFECT LUNAR ECLIPSE

Don't miss the chance to photograph this month's unusual total lunar eclipse low on the horizon.

by David J. Eicher



George Washington would be proud. On his 257th birthday, celebrated February 20, one of the prettiest celestial events of the year — a total lunar eclipse — will take place. Early on this Monday morning, observers in western North America will see a slightly darkened, eclipsed Moon slip under the western horizon as the sky brightens before sunrise. In addition to the eclipse, observers in Hawaii get to see the Moon occult Regulus, the brightest star in Leo, three hours before the eclipse begins.

This eclipse is a wonderful opportunity for observers and photographers. With a 35mm SLR camera fitted with a standard or telephoto lens, a sturdy tripod, and a roll of fast color film, you can get beautiful results with exposures of just several seconds.

A lunar eclipse occurs when Earth passes between the Sun and Moon and temporarily casts a shadow on the Moon's disk, blocking sunlight that normally reflects off the Moon's surface and thereby darkening the Moon for a couple of hours.

Like all eclipses, a total lunar eclipse takes place in stages. This month's eclipse begins when the Moon's disk enters the penumbra, the relatively light outer region of Earth's shadow, on the 20th at 12 hours 29 minutes universal time or 4:29 a.m. PST.

During the next six hours and twelve minutes the Moon's disk will move through Earth's shadow, enter the umbra — the central, darkest part of the shadow — reach a point of mid-eclipse, leave the umbra, and leave the penumbra. The eclipse ends at 18 hours 41 minutes UT.

Viewing this month's eclipse is complicated because the eclipse occurs shortly before moonset for most U.S. observers. Whether or not you will be able to see the eclipse — or see it during its most impressive, darkest minutes — depends on your location. Generally, the farther west

February 20 Eclipse Timetable

Location	Enters Penumbra	Enters Umbra	Mid-Eclipse	Moonset
Albuquerque, New Mexico	5:29 a.m.	6:43 a.m.	—	6:50 a.m.
Anchorage, Alaska	3:29 a.m.	4:43 a.m.	6:35 a.m.	7:35 a.m.
Boise, Idaho	5:29 a.m.	6:43 a.m.	—	7:40 a.m.
Butte, Montana	5:29 a.m.	6:43 a.m.	—	7:29 a.m.
Calgary, Alberta	5:29 a.m.	6:43 a.m.	—	7:45 a.m.
Denver, Colorado	5:29 a.m.	6:43 a.m.	—	6:49 a.m.
Honolulu, Hawaii	2:29 a.m.	3:43 a.m.	5:35 a.m.	7:04 a.m.
Las Vegas, Nevada	4:29 a.m.	5:43 a.m.	—	6:26 a.m.
Los Angeles, California	4:29 a.m.	5:43 a.m.	—	6:35 a.m.
Portland, Oregon	4:29 a.m.	5:43 a.m.	—	7:09 a.m.
Salt Lake City, Utah	5:29 a.m.	6:43 a.m.	—	7:18 a.m.
San Francisco, California	4:29 a.m.	5:43 a.m.	—	6:57 a.m.
Seattle, Washington	4:29 a.m.	5:43 a.m.	—	7:12 a.m.
Vancouver, British Columbia	4:29 a.m.	5:43 a.m.	—	7:18 a.m.

All times given in local standard time.

A RUDDY MOON HOVERS over the mountains during the lunar eclipse of July 6, 1982. Photo by Tom Bullock.

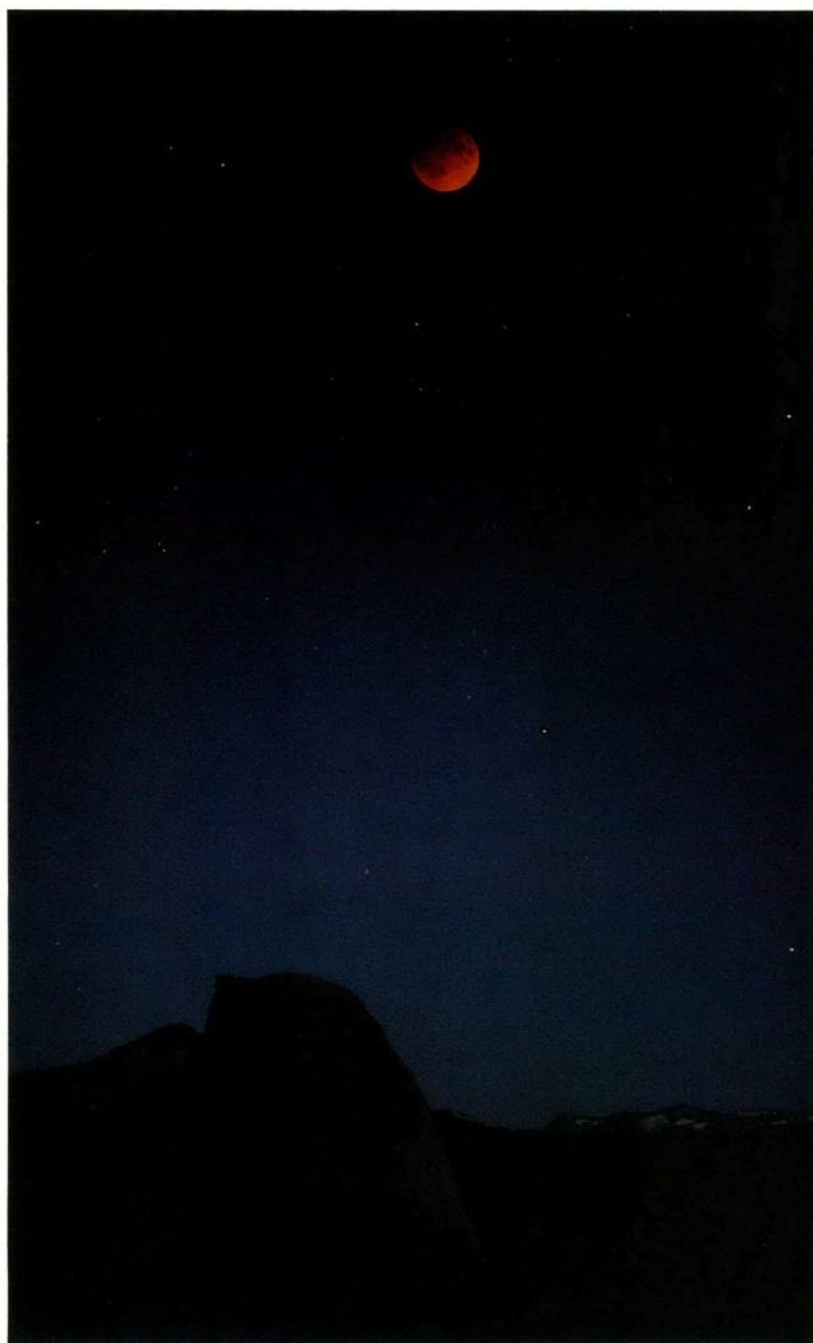
you are, the better. Observers in the East will not see the eclipse.

In the Western Hemisphere the beginning of the umbral eclipse is visible west of a line extending from western Greenland south through the central plains and northwestern Mexico. The best viewing will be from the Pacific Coast, especially the Pacific Northwest, and in Hawaii, where the eclipse takes place with the Moon high in the sky.

If you live in Albuquerque, Denver, Salt Lake City, or anywhere else in the mountain time zone, you will be able to see the beginning of the eclipse before moonset. Observers in Denver, for example, will see the Moon enter the penumbra at 5:29 a.m. MST and enter the umbra shortly before the Moon sets at 6:49 a.m. Because Salt Lake City is farther west and north, viewers there have an additional 29 minutes to watch the eclipse before the Moon sets. Pacific Coast observers will see the first half of the eclipse before moonset.

Observers in Honolulu will see the Moon cover Regulus at 12:09 a.m. and then see the star reappear at 1:26 a.m. One hour and three minutes later the eclipse will begin. The Moon enters the umbra at 3:43 a.m., and mid-eclipse occurs at 5:35 a.m. The Moon sets in Hawaii at 7:04 a.m., shortly before the eclipse's final stage is over.

Set your alarm for early on Washington's birthday. If you get up and the sky is clear, take a camera loaded with fast color film along to see the eclipse. You'll come away with scenic shots of the eclipsed Moon as it drops toward the horizon — a personalized souvenir of one of the prettiest scenes in nature. □



Legendary Faint Galaxies

These galaxies are so faint, distant, or heavily obscured that they'll test the observing skills of even the most determined observer.

by Steve Lucas

Have you ever seen a *really* faint galaxy? If not, you're missing one of the great challenges of backyard observing. If you have, you know that seeing a faint galaxy tests your visual acuity, sharpens your observing skills, and rewards you with a glimpse of a very distant or low surface brightness object that few on this little planet have observed firsthand.

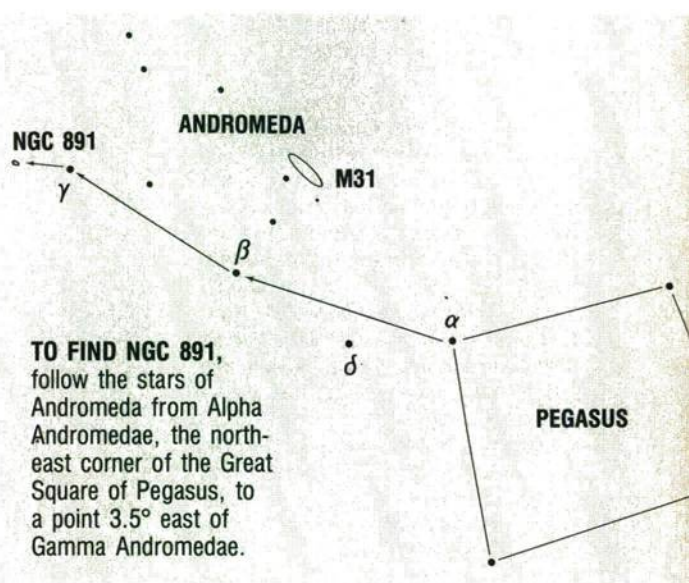
Galaxies are challenging targets for backyard telescopes because they are dim objects. Some galaxies are extremely distant and therefore appear dim — many are not much brighter than the sky background itself. Others are near us in space but are intrinsically dim, generating a small fraction of the light output of a normal spiral galaxy. Still others are bright and relatively close, but their light is obscured because they lie behind the disk of the Milky Way.

NGC 891 is the best all-around challenging galaxy in the winter sky. Located 3.5° east of the star Gamma Andromedae, NGC 891 is a magnitude 10.0 spiral galaxy that measures $13.5'$ by $2.8'$ in extent. It is an edge-on galaxy with a broad dust lane that splits it in half. Because of its inclination, dust lane, and large size, NGC 891 has an extremely low surface brightness. Therefore NGC 891 appears much fainter — and is trickier to find and observe — than its magnitude suggests.

To find NGC 891, insert a low-power eyepiece in your scope. This provides a wide field of view and a reasonably contrasty image of the galaxy. Aim the scope at Alpha Andromedae, the star that marks the northeastern corner of the Great Square of Pegasus. Follow the southern arc of bright stars that forms Andromeda by moving from Delta to Beta and on to Gamma Andromedae. From Gamma, move 3.5° east. In your finder scope you should see a double star with 6th- and 7th-magnitude components. NGC 891 lies 1° north of this double star.

Once you locate NGC 891, what you'll see depends on the telescope you are using. The galaxy is a challenge to see at all with a 2-inch or 3-inch telescope and shows a sliver of pale light oriented northeast-southwest that measures $6'$ across and lies in a field strewn with faint stars.

Six-inch telescopes easily show NGC 891, but with this size instrument the challenge is spotting detail in the galaxy. On all but the poorest nights a 6-inch scope reveals the galaxy's broad dust lane. A 6-inch scope at 100x shows the galaxy's central hub — the brightest part of NGC 891 — that measures some $3'$ long. The disk of NGC 891 is visible as a faint extension some $3'$ long on



both sides of the galaxy's center.

Large telescopes show more detail and provide a brighter overall image of NGC 891. They also crowd the field with groups of faint stars. In a 12-inch telescope the central bulge of NGC 891 appears reasonably bright and is surrounded by an amorphous glow of light that smoothly tapers down to sharp points on each end. At high power the dust lane's edges appear slightly rough, and a faint star (approximately magnitude 12) shows up near each end of the galaxy, embedded in the galaxy's light.

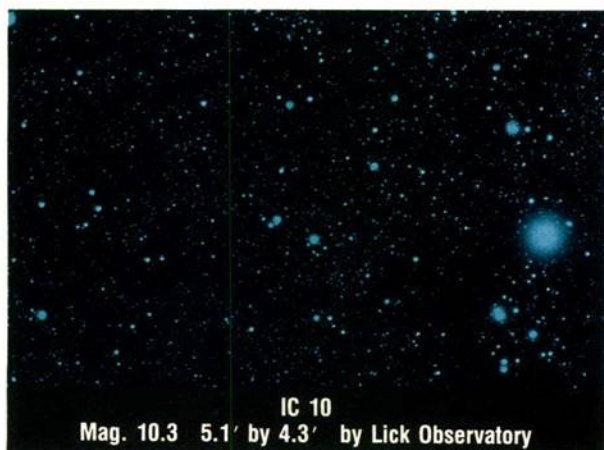
When you observe NGC 891, take advantage of a few tricks of the trade to see as much as you possibly can. After locating the galaxy, switch to a medium-power eyepiece (about 15x per inch of telescope aperture). This will provide a dark-sky background, which is an ideal background for seeing faint details in the galaxy. Move your eye around the field of view, looking directly at the galaxy and also off to an edge of the field: this lets you use the part of your retina that is most sensitive to faint light. Also, move the telescope ever so slowly in a circular pattern while keeping the galaxy somewhere in the field. Human vision is sensitive to motion, so this movement could help you see detail in the galaxy.

After viewing NGC 891, move on to Cassiopeia's IC

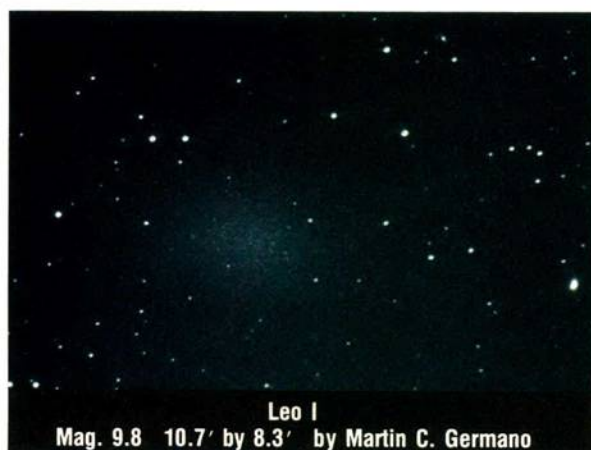


NGC 891
Mag. 10.0 13.5' by 2.8' by Ron Potter and Jack Marling

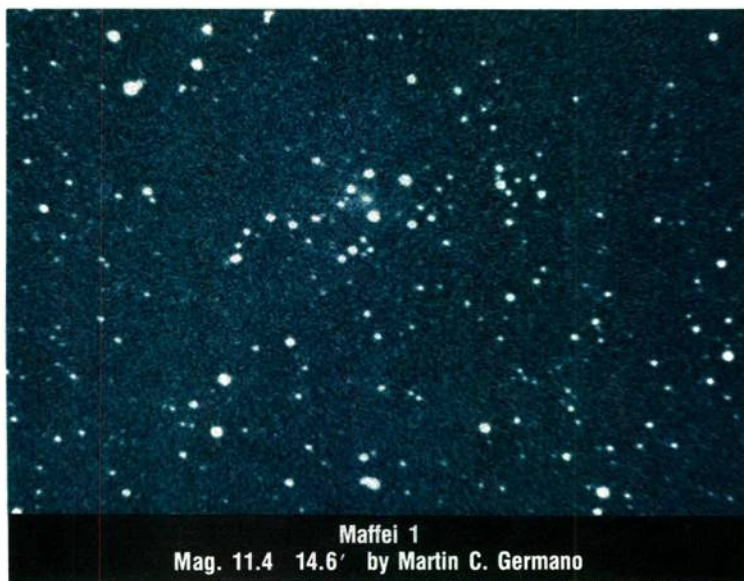
DIM DWARF GALAXIES IC 10 and Leo I are challenging targets for small telescope users because the objects are inherently faint. NGC 891 is a low surface brightness edge-on galaxy with a hard-to-glimpse dust lane.



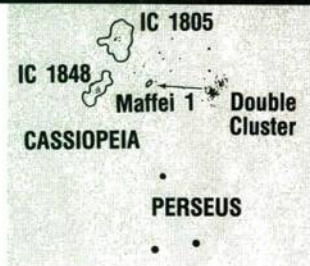
IC 10
Mag. 10.3 5.1' by 4.3' by Lick Observatory



Leo I
Mag. 9.8 10.7' by 8.3' by Martin C. Germano



HEAVILY OBSCURED
Maffei 1 would be one of the brightest galaxies if it didn't lie directly in the thick of the Milky Way. Instead it is a challenge for the largest amateur telescopes.



Challenging Winter Galaxies

Object	R.A.(2000.0)	Dec.	Mag.	Size	Tirion	Uranometria
IC 10	0h20.4m	+59°18'	10.3	5.1' by 4.3'	—	I: 35
NGC 891	2h22.6m	+42°21'	10.0	13.5' by 2.8'	1, 4	I: 62
Maffei 1	2h36.3m	+59°39'	11.4	14.6'	—	I: 38
Leo I	10h08.4m	+12°18'	9.8	10.7' by 8.3'	13	I: 189

Object: Designation in NGC, IC, or other catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of galaxy. **Size:** Diameter in arcminutes. **Tirion:** Chart on which object appears in *Sky Atlas 2000.0* by Wil Tirion. **Uranometria:** Chart on which object appears in *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi.

10, an even more challenging object. IC 10 is an irregular galaxy that lies on the outskirts of our Local Group of galaxies. Although it is close to home in an extragalactic sense, IC 10 is difficult to observe because it is intrinsically much fainter than a galaxy like NGC 891 and is obscured by the rich Milky Way in Cassiopeia.

IC 10 is easy to find: simply move your scope 2° east of Beta Cassiopeiae, the westernmost star in the "W" of Cassiopeia. Once you locate the galaxy's position, switch to a low-power eyepiece and look for a small "spot" of faint, milky light. In a 10-inch telescope IC 10 appears as a faint round glow, not more than 1' across, lying in a field containing TV Cassiopeiae, which varies between magnitudes 7.2 and 8.2.

Still more challenging is the low surface brightness galaxy **Leo I**. Leo I is a dwarf elliptical galaxy in our Local Group. It is intrinsically faint and small, and we see it only because it lies reasonably close. This galaxy is especially challenging because it lies 20' north of Regulus, one of the brightest stars in the sky. The glare from Regulus overwhelms the faint light from Leo I,

which makes sighting the galaxy extremely challenging even with a large-aperture telescope.

To see Leo I, try using at least a 10-inch telescope. Aim your finder scope at Regulus and move the telescope a couple of degrees north. Insert a high-power eyepiece in the telescope, one that provides a 15' field of view. Slowly move the telescope south toward Regulus looking for a faint glow, but make sure to stop short of reaching Regulus. If you don't, you'll flood your eye with photons and have to wait fifteen minutes to regain your dark adaptation.

Another method of observing Leo I is placing an occulting bar in front of Regulus, blocking the star's light but allowing light from faint stars — and Leo I — to reach your eye. To do this, cut a small piece of opaque material and tape it over one edge of the eyepiece lens. When you observe Leo I, make sure that light from Regulus is blocked by the bar.

The most challenging galaxy in the winter sky is **Maffei 1**, a heavily obscured object buried behind the Cassiopeia Milky Way. Discovered by Italian astronomer Paolo Maffei in 1968, Maffei 1 is a large spiral galaxy on the outer fringes of our Local Group — reasonably close but blocked by gas clouds and dust in our own Galaxy. If it were located in a barren region of sky, Maffei 1 would be one of the finest galaxies in the sky.

However, it isn't. Wedged between the Double Cluster in Perseus and the big bright clusters IC 1805 and IC 1848, the position of Maffei 1 is not difficult to find. Start by moving 2° northeast from the Double Cluster to a group of four 7th-magnitude stars, three forming an isosceles triangle. From there move 1.5° north to a double composed of 7th- and 9th-magnitude stars. Now move 3/4° northeast to a wide pair of 8th-magnitude stars. (The easternmost is a double.) Maffei 1 lies 15' south of this wide pair.

Confusion reigns when it comes to sighting Maffei 1. Although amateurs can photograph this galaxy with long exposures, visual sightings are extremely difficult even with large apertures because the galaxy is really faint. Moreover, a little clump of very faint stars lies practically on top of the galaxy's center. In all likelihood many amateur sightings of Maffei 1 are really sightings of this clump of stars.

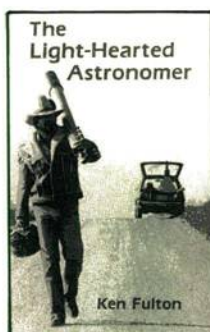
Observing these faint galaxies in the winter sky will challenge you in quite different ways. The overall low surface brightness and elusive detail of NGC 891 is within range of most amateur telescopes on cold, clear nights — all you need is persistence and a careful eye. IC 10 heightens the challenge of seeing an extremely faint object. Leo I, fainter still than IC 10 and adjacent to one of the sky's brightest stars, tests the most experienced and best-equipped backyard observers. And Maffei 1 lies behind a sprinkling of faint stars, which forces you to make sure you're seeing the galaxy and not unresolved light from distant stars.

As you warm up indoors and contemplate successes or failures, you can dream up new strategies — among them occulting bars, averted vision, and slow sweeping — to help pull in photons from some of the toughest deep-sky objects in the sky. □

Steve Lucas is the coordinator of "Sunsearch," a network of amateur and professional astronomers who search for supernovae in other galaxies.

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A simple mask on your reflector produces cleaner images of double stars and planets.

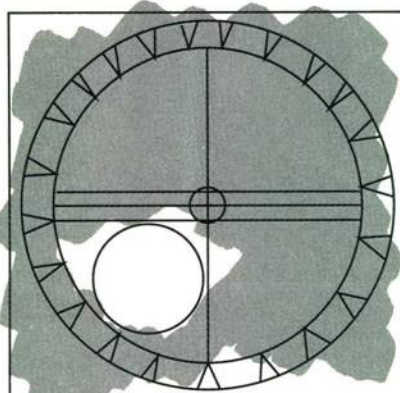
by M. Leon Knott

Is your telescope plagued by fuzzy images? Large, short-focus reflectors provide excellent views of galaxies and nebulae but usually do not give satisfying views of resolution-critical objects like double stars and planets. The same telescope that makes you say "Wow!" when you look at the Andromeda Galaxy makes you say "Yuk!" when you look at Saturn.

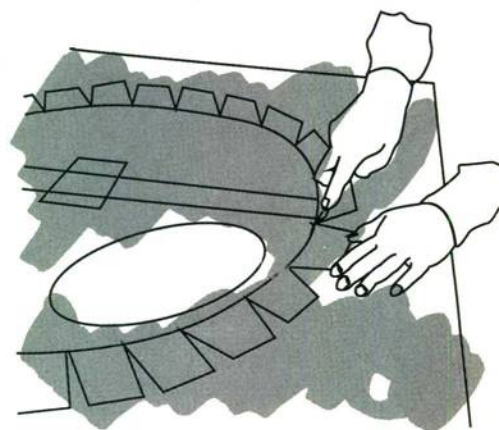
Three factors — seeing, collimation, and diffraction — contribute to the less-than-sharp images of bright, detailed objects your telescope delivers. Seeing is the least controllable of the three. About all you can do is make the atmosphere work for you: concentrate on viewing deep-sky objects on nights when the atmosphere is less than perfectly calm. When seeing is steady, you can observe the Moon and planets and take advantage of the high powers that show lunar and planetary detail so well.

Collimation is another critical factor. Although properly aligning your telescope's mirrors is vital, it's often something that gets done too quickly and somewhat carelessly. Make sure you spend enough time collimating your mirrors so alignment is as precise as possible. This will help eliminate odd-shaped stars and a loss of detail caused by scattered light. (See "Collimating Your Telescope" by Richard Berry and Robert Burnham, January 1981, and "Updating Newtonian Collimation" by D. Eric Allen, *Telescope Making* #22, Spring 1984.)

Even if you've properly collimated your telescope and you're observing on an exceptionally steady night, diffraction can ruin planetary observing. Diffraction occurs in a reflecting telescope when light that enters the scope strikes the secondary mirror mount and is scattered. This produces dirty, "flared" star images. Fortunately there is an easy, inexpensive fix for diffraction that also alleviates problems



OUTLINE THE END of the telescope tube and an off-axis hole on black cardboard.



CUT THE MASK on a hard, smooth surface with a sharp X-acto knife.

caused by seeing and collimation — make your big scope a small scope.

Small Scope Advantage

You can reduce the aperture of your telescope with an off-axis mask that is placed over your reflector's front end. The mask is simply a sheet of heavy cardboard with a hole cut out that allows starlight to travel through the scope's optical system to your eye while avoiding the secondary mirror mount. Thus, the big reflector that delivered fuzzy images becomes a small reflector that delivers sharp images.

A small aperture works best for high-resolution observing because it helps you minimize the effect of unsteady seeing. Starlight passes through little convective cells of air that are either stable or in a state of turbulence before reaching your eyepiece. Large apertures produce fuzzier images than smaller apertures because the collected light has passed through a larger volume of air. By reducing the aperture, you limit the effect of unstable seeing. The result is crisper images.

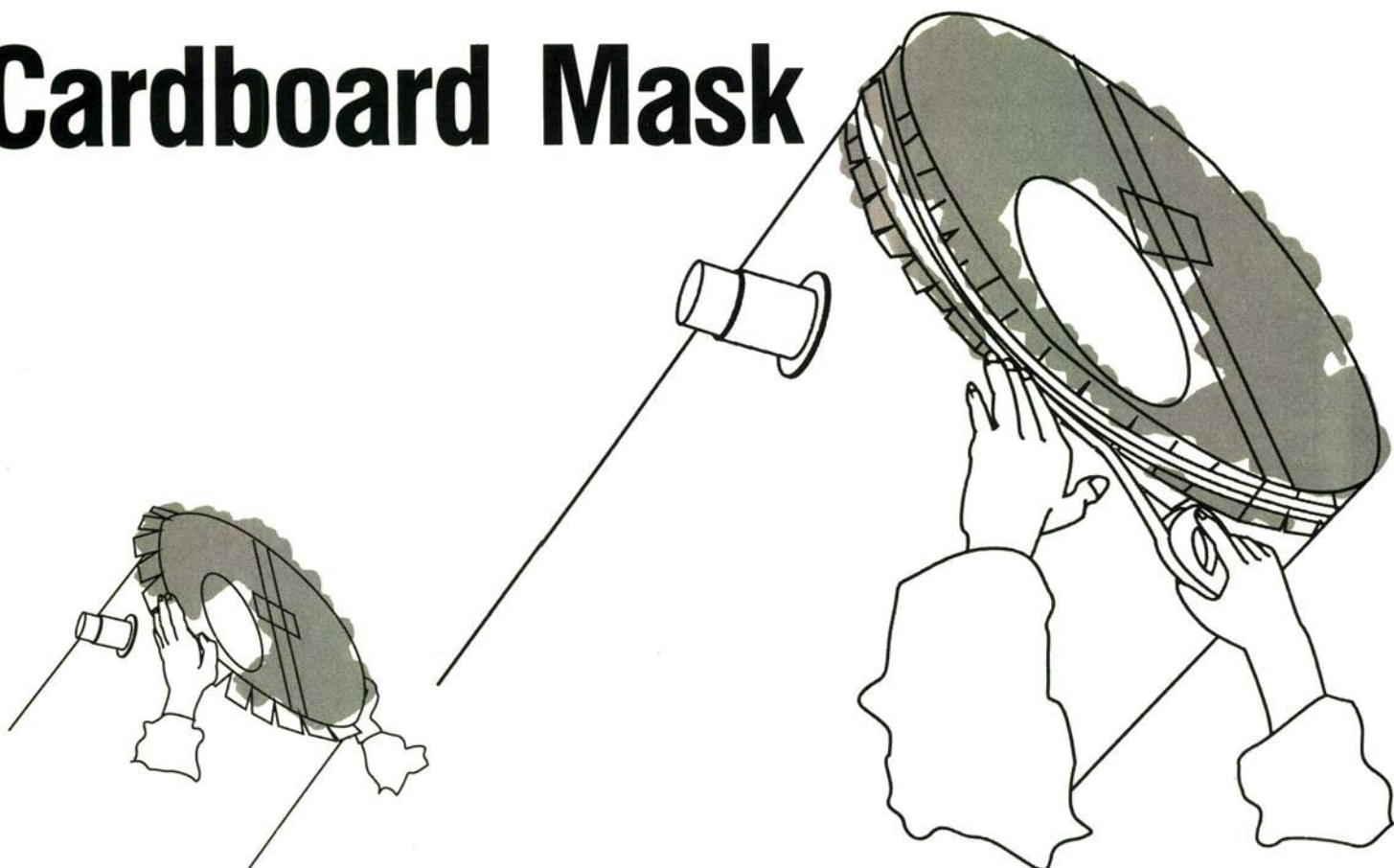
Small apertures are also far easier to

successfully collimate than large apertures. Big mirrors require lots of adjustment to achieve perfect alignment, whereas smaller mirrors have smaller ranges of adjustment and are more forgiving. If a big scope is out of collimation, you'll know it — the bright images plainly show collimating flaws. Smaller apertures, however, provide dimmer images, so small flaws in collimation are not as readily apparent.

Diffraction is generally less severe in small apertures because the images are dimmer. There is simply less light to scatter than in big scopes. An off-axis mask eliminates the problem of diffraction because the hole that allows light to enter the telescope completely misses the diagonal mount and the light has an unobstructed path.

Stopping down your reflector also means that the selection of eyepieces you use isn't critical; you won't see defects in eyepieces as much as you would with a large, short-focus telescope. An eyepiece that yields awful images with a big mirror may appear

Cardboard Mask



PLACE THE OFF-AXIS HOLE so light entering the scope misses the diagonal.

TAPE THE MASK INTO PLACE with duct tape. This will hold the mask firmly in place and allow you to remove it when you're finished.

to give reasonably good images with the same mirror stopped-down with a mask.

Masks also help out mediocre mirrors. Reducing the aperture to a fraction of the original helps hide optical defects in mirrors because the images they deliver are not as bright. Furthermore, the quality of a mirror's figure varies over its surface. By star-testing the images, you can rotate the mirror so a good section of the mirror lies within the light path.

Constructing a Mask

To make a stop-down mask, you need a sheet of black cardboard larger than the diameter of your telescope's tube by several inches on each side. You also need a pencil, a tape measure, a geometric compass, duct tape, an X-acto knife, and a clean surface on which you can cut the cardboard.

Place the sheet over the end of your telescope and use the pencil to draw a line on the cardboard around the circumference of the tube. Mark on the cardboard the position and size of the diagonal mirror and diagonal holder on the cardboard. This allows

you to cut the mask's hole in a position that will miss the diagonal holder.

Next, draw several tabs spaced equally around the circle on your cardboard sheet. These tabs will be bent down and fastened to the side of the telescope tube with a few small pieces of duct tape. The number and position of the tabs aren't critical, you just need the tabs to fit the mask snugly over the telescope tube.

Now you're ready to cut the mask's hole. On the cardboard sheet, draw a small circle in a place that misses the diagonal holder. The best general rule is to make the hole as large as possible while still missing the diagonal assembly. The edges of this hole should be cleanly cut. If you find it difficult to cut clean edges in thick cardboard, cut a clean hole in a thin piece of black art paper and tape the paper into a larger hole in the cardboard sheet. You may prefer to do this anyway, because it's easier to cut paper neatly than thick cardboard.

You might also want to experiment with the shapes and sizes of your mask's holes. While a circle is best in

providing an absolutely uniform image, squares, ovals, triangles, or other shapes may yield different results.

If you're so inclined, make a few masks of different shapes and take them out under the stars. Try each one in succession on a bright object like Saturn and make careful notes about its appearance with each mask. You'll see that the image quality varies slightly with the shape of the mask. It's probably safe to say that the best overall shape for a mask is a circle, although ovals work well too.

If you own a large reflector with a short focal length, you owe it to yourself to spend half an hour and a few dollars to optimize your telescope. When you do, you'll see that galaxies aren't the only objects worth observing: Saturn and Mars are pretty amazing too! □

M. Leon Knott is the curator of physical science and the planetarium director at the Museum of York County in Rock Hill, South Carolina.

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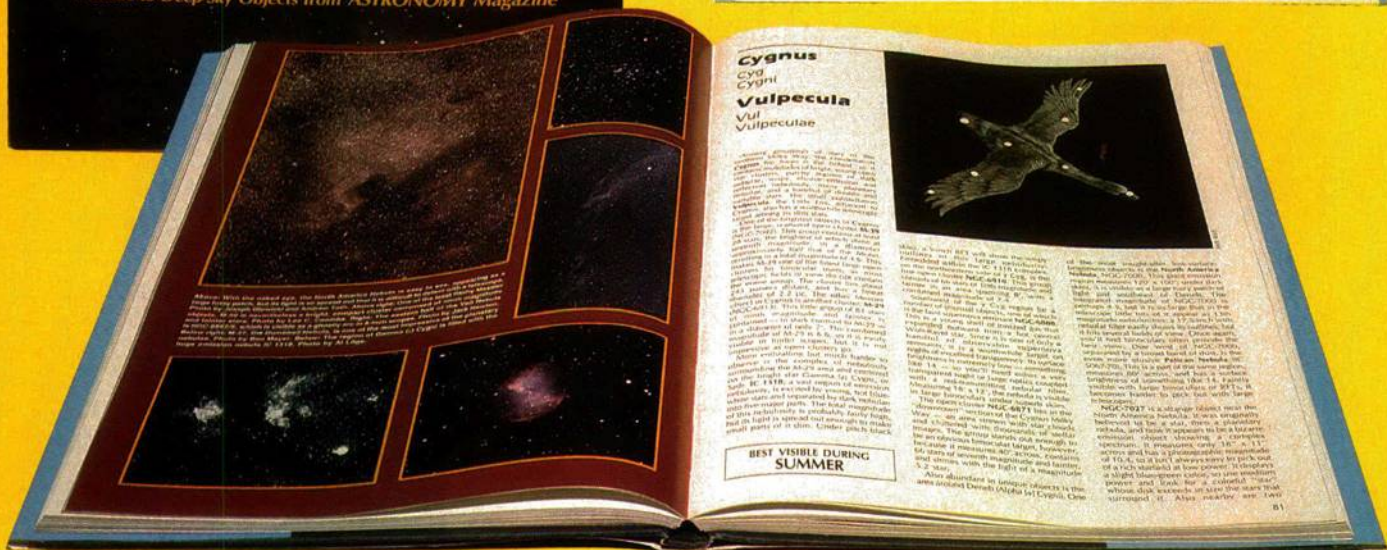
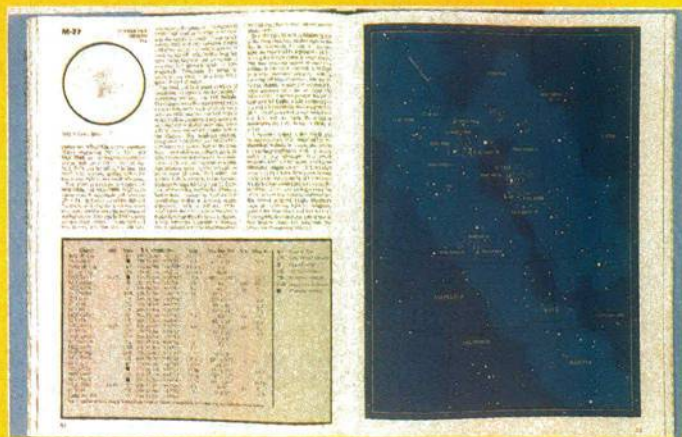
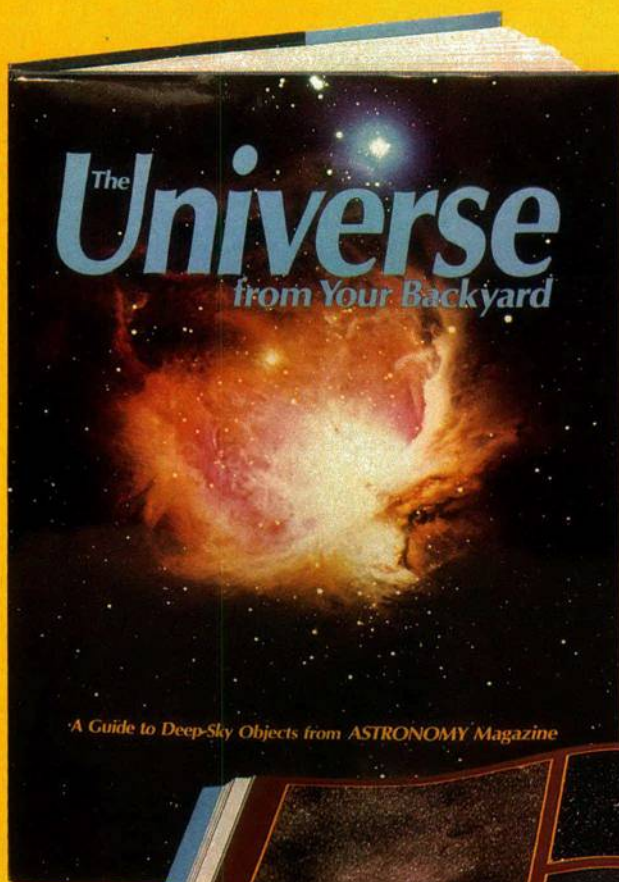
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Working against the Grain of Fast Films

Multiple printing can average out the graininess of fast films and improve detail in your astrophotos.

by Larry Myers

Konica SRV 3200 is a remarkably fast color negative film that yields great results for many astrophotographers. Its one drawback, however, is grain — the inescapable photographic “noise” that limits the detail your photos can record and weakens pictorial impact.

But you don't have to tolerate *all* the grain this film gives you. If you are set up to make color prints in your own darkroom, you can reduce the grain in your photos with a simple technique called integration or composite printing. Instead of making your final print from a single negative, you print from two or three separate but identically framed negatives.

In technical terms, this process improves the signal-to-noise ratio. The “signal” (stars, dust lanes) repeats in exactly the same place from one negative to the next, while the “noise” (grain) does not, because it is scattered randomly throughout each negative. The result of integration printing is that stars and other valuable details are enhanced and the distracting grain is smoothed out.

Wanted: Three Identical Negatives

The key to making a successful integration print is printing all component negatives *precisely* in register. The most practical way to do this is shooting three identical photos of an object, one right after the other, on the same night, with the telescope tracking the same guide star. Shoot the photos near the meridian, keep the exposures equal in length, and do not adjust the focus between frames.

Take enough exposures so that you will have three photos to work with. Keep the exposures short: You'll guide better and your final print will be sharper.

AN EASEL MAKES IT EASY to create trouble-free composite prints that feature improved detail and reduced graininess.

Let's now assume you have three identical negatives of some object.

An Easel Makes It Easy

Step one is making a registration easel. The photo below shows the one I made from some matte board I bought at an art supply store. I make 8x10 prints, so my easel measures 11 inches by 14 inches. If your paper is larger or smaller, scale your easel accordingly. (I find it's easier to make integration prints that are 8x10 or 11x14 inches in size than to make smaller ones. With small prints it is harder to catch misalignments in registration.)

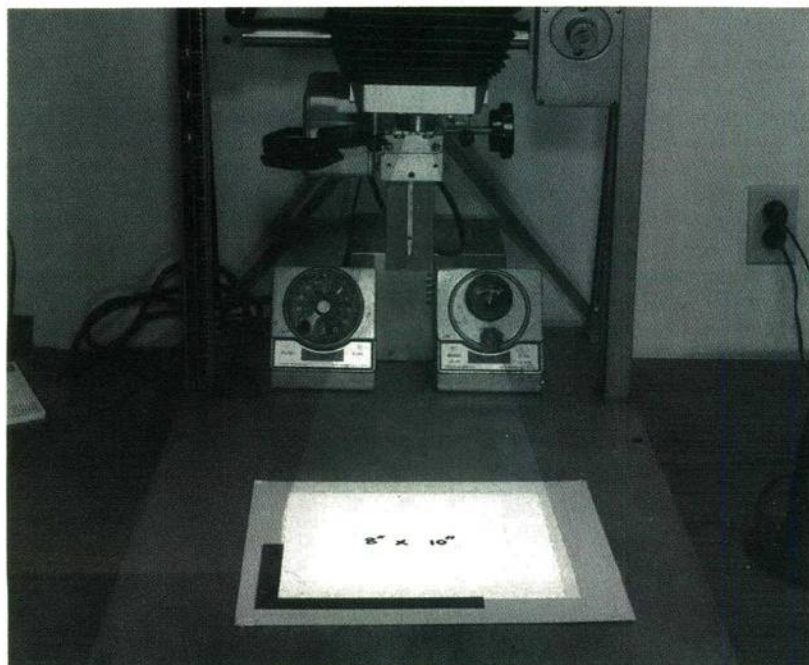
The L-shaped guide on the left has an inside angle of 91°. Place a sheet of print paper along the bottom edge and slide it to the left until it meets the upright edge. Because the “L” is slightly more open than a true right angle, the bottom edge of the sheet will always slide precisely into the

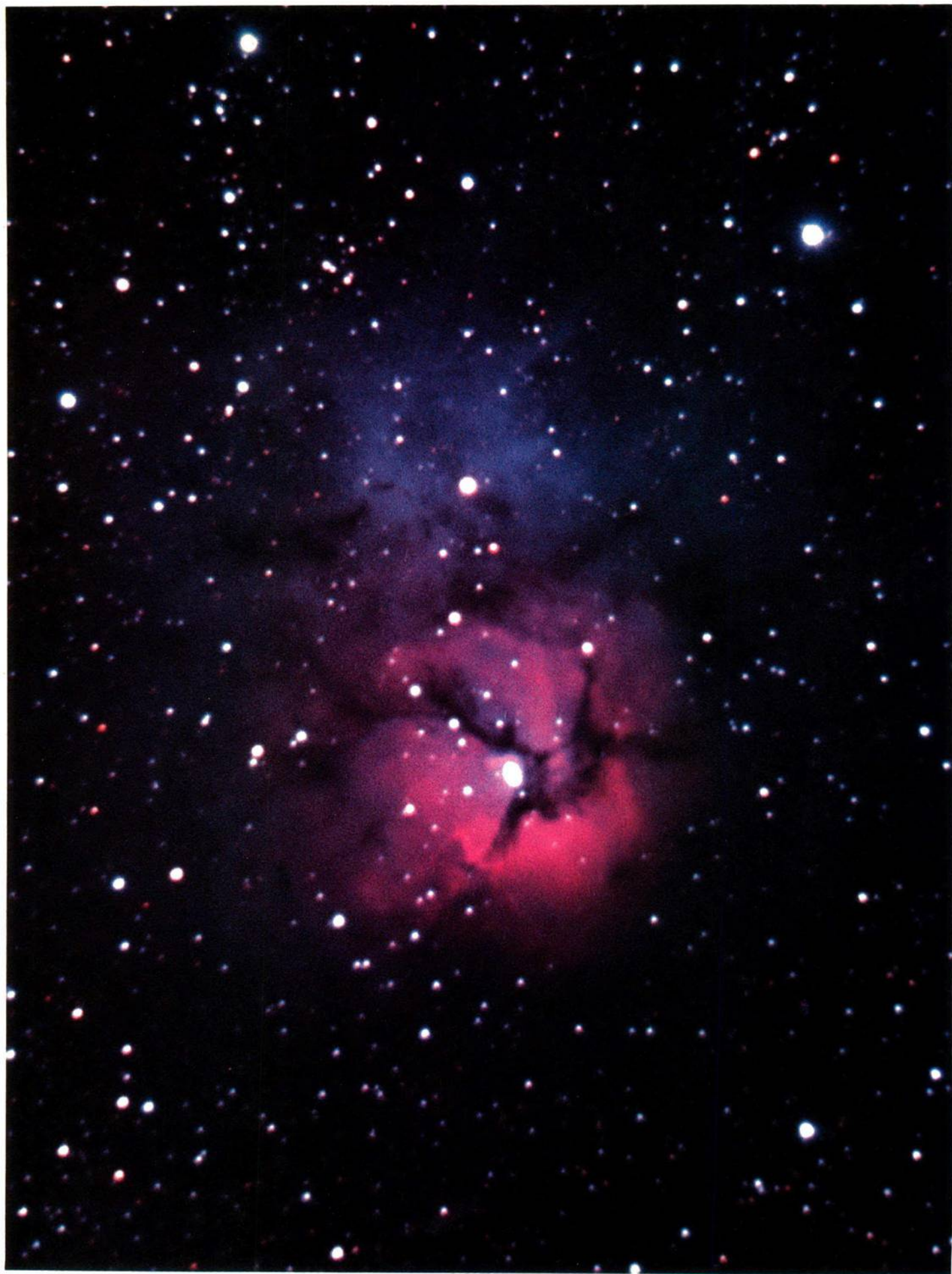
inner corner.

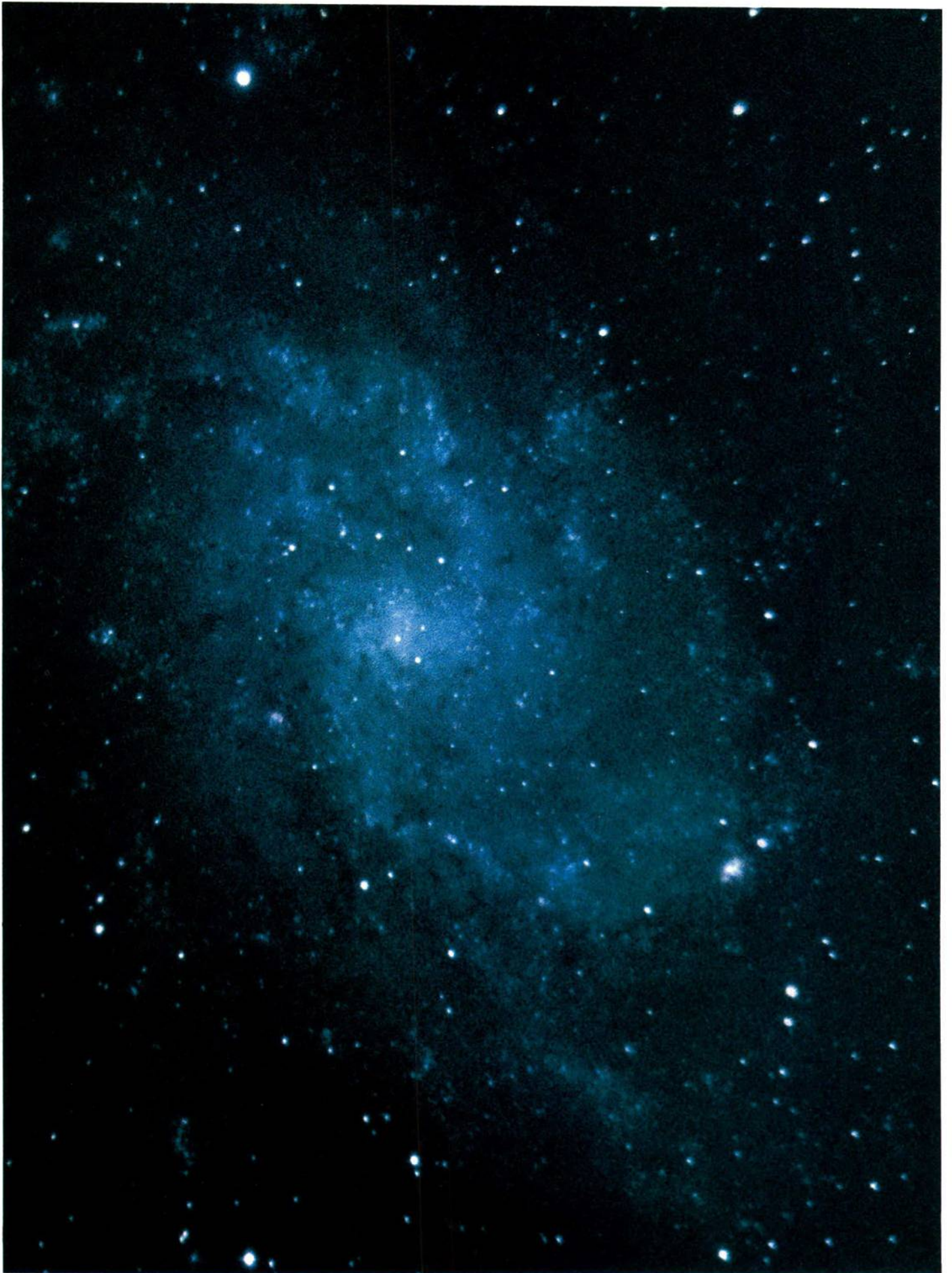
Now take one of the identical negatives and make a “register print.” This print will be used to line up each of the three negatives when you composite-print them. Choose the middle negative in the series, put it in the enlarger, and focus on the back of a discarded print positioned in the “L” of the easel. Place the easel so the image includes only what you want and then fix it into place on the base-board with masking tape.

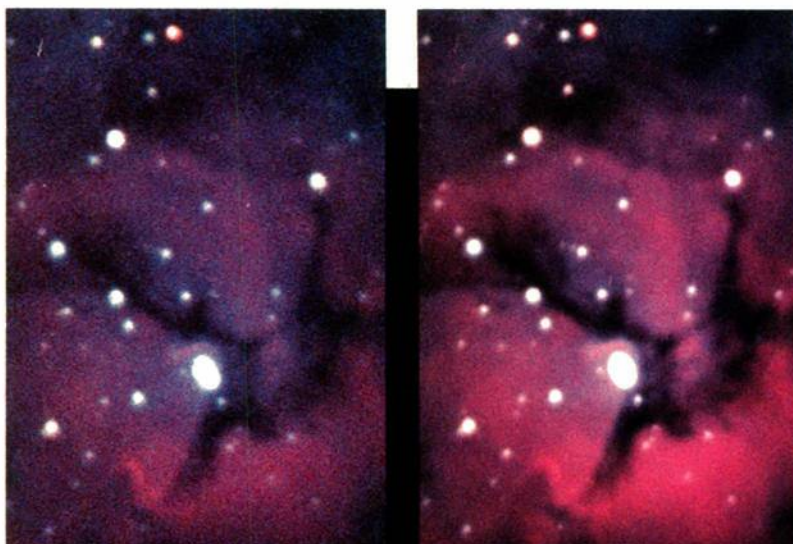
Remove the focus sheet, douse the lights, and slide a fresh sheet of print paper into place on the easel. Expose, develop, and dry this print as you normally would, taking time to get the

CRISP DETAIL but softened grain are the results of printing four negatives of the Trifid Nebula onto the same sheet of photo paper. (All astrophotos by the author.)









A SINGLE NEGATIVE of the Trifid Nebula makes a print that looks good (far left), but a composite of four negatives looks even better.

THE DUMBBELL NEBULA shows how much improvement results from using two negatives (far right) instead of one.

color balance and exposure just right. Make a note of the enlarger height, filter combination, f/stop, and exposure time that produce a good-looking print.

Now you are ready to make the actual composite print. Position the register print on the easel (which is still taped in place) with the image facing up. Slide the first of your three negatives into the enlarger. You will know the negative is placed correctly in the enlarger when the print on the easel turns gray because the dark spots on the negative lie exactly on top of the light spots on the print and the two cancel each other.

Turn off the enlarger and check that the filtration and f/stop are the same ones you used to make the registration print. Remove the register print from the easel and replace it with a fresh sheet of print paper. Before putting it on the easel, take a tiny snip off one corner (the upper right, for instance), so you can orient the sheet properly on the easel in total darkness.

Three Partials = One Whole

To expose the print, divide your

register-print exposure in half or in thirds, depending on the number of negatives you have. Turn on the enlarger for the required time. Then remove the print and place it in a light-tight container. Put the register print back on the easel and move the next negative into place. Don't try to achieve register by moving the easel! You'll get distortions if you move the easel rather than the negative in the enlarger.

When the register print goes gray again, turn off the enlarger, remove the register print, and place the already exposed sheet back on the easel, checking that the snipped corner is oriented properly. Turn on the enlarger for the second exposure. Do the same for the third negative and then process and dry the print.

Now turn on the room lights and check the composite print. If you've done things right, the integrated print should be a crisp image with the same color and darkness as your register print but with less grain and better detail. If the composite print isn't quite as sharp as the register print, you probably didn't hold register precisely enough during the procedure.

There are two reasons I recommend a maximum of three negatives — though, as the photo captions will tell

you, I have broken this rule myself on occasion! First, the more times you remove the sheet from the easel, the less likely you'll be to put it back *precisely* in place, notwithstanding the care you take.

Second, printing paper doesn't respond in density or color in exactly the same way to five 10-second exposures as it does to one 50-second exposure. This "intermittency effect" won't trouble you much with a small number of exposures, but compositing a slew of negatives will give less satisfactory — and less predictable — results.

Integration printing may sound like a lot of work for a single photo, but I've found that with a little practice you can run through the whole sequence in about 6 or 7 minutes.

Konica 3200 is a grainy film, but this technique can reduce the grain to tolerable levels. It also works with other grainy films, so if you've been shooting astrophotos on some of the older black-and-white emulsions, give this method a try. □

Larry Myers lives in California and has been an astrophotographer for several years. He thanks Phil Mattingly for his help in preparing this article.

THREE NEGATIVES COMBINED enhance the star clouds and spiral arms of M33, the Pinwheel Galaxy in Triangulum.

AMATEURS RECORD MARS WITH CCD

Members of California's Santa Barbara Astronomy Club recorded Mars with a charge-coupled device camera during the recent Martian opposition. They used the 16.5-inch Cassegrain telescope at Westmont College in Santa Barbara and proc-

essed the images there, creating some of the first CCD images of Mars made by amateurs.

Thomas W. Fuller, the project's coordinator, said, "We recorded CCD images of Mars as a part of a three-pronged effort to supply observations to the Association of Lunar and Planetary Observers (ALPO). Other Santa Barbara members have made drawings from visual observations and taken photographs."

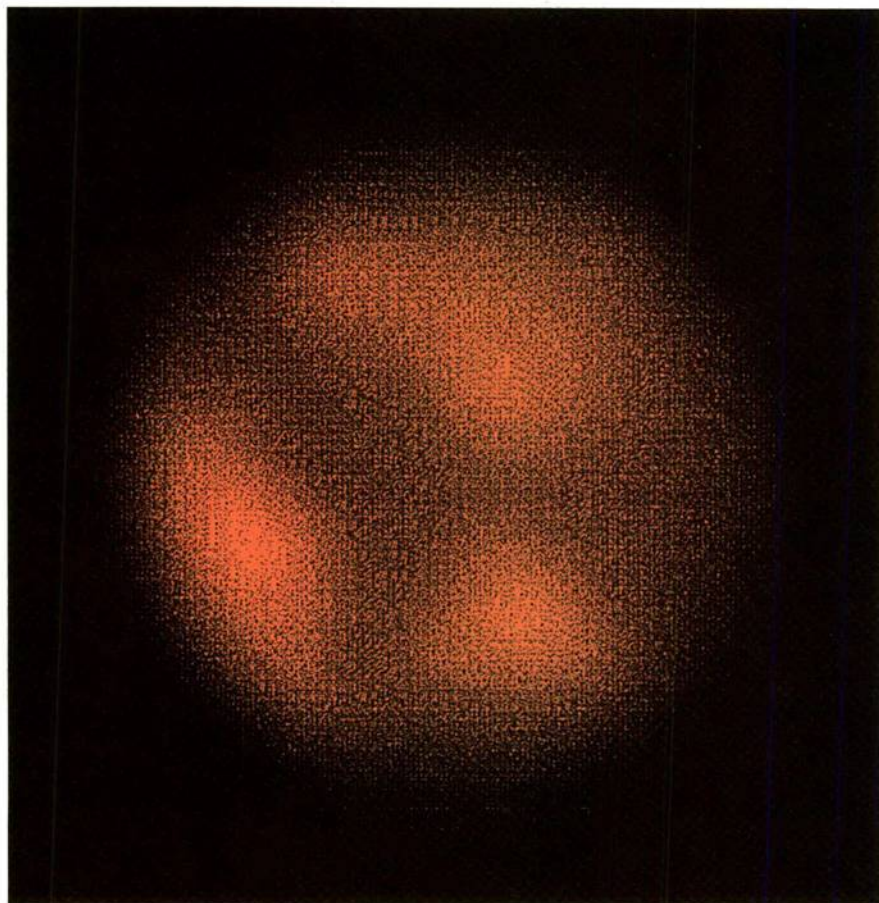
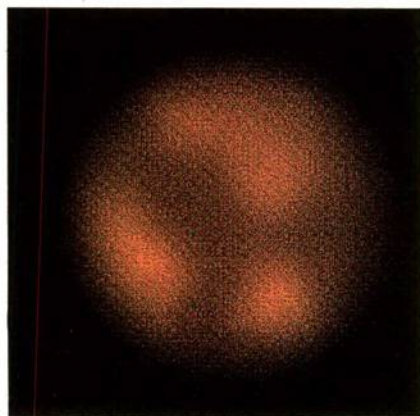
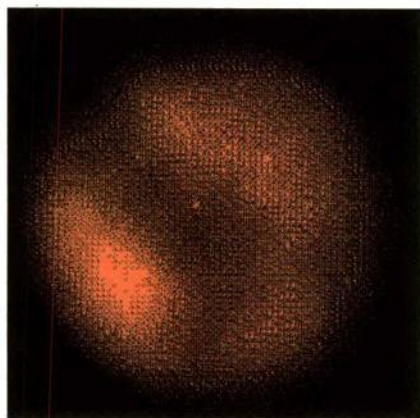
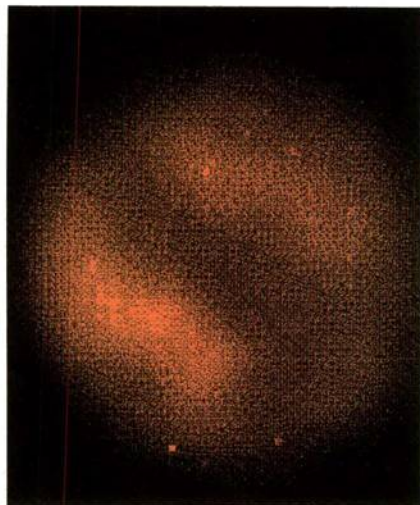
To sharpen the Westmont telescope's images, Fuller employed a 5-inch off-axis mask over the scope's front end. He then tested filters to record yellow, red, and violet images of the Red Planet. The exposures fed to the CCD camera lasted about 1/8-second each and were made by hand using a cardboard shutter.

"The images represent raw data that has only been processed in the sense that the aspect ratio has been corrected," said

Fuller, referring to the relationship of length to height in the images. "The image intensity has also been normalized to use the full range of a 256-step gray scale. After this processing, we printed the images on a high-resolution dot-matrix printer."

Assisted by club members Clyde Kirkpatrick and Ramona White, Fuller made a sequence of four images on October 8, 1988, that showed the rotation of Mars. Each view was made with a different filter. "The last frame was especially exciting because we made it with a violet filter and later found out that it was made during a violet clearing," said Fuller. A violet clearing is a period when the Martian atmosphere seems to rapidly clear.

The Santa Barbara group plans to continue producing CCD images of Mars as the Red Planet continues on its journey away from opposition.



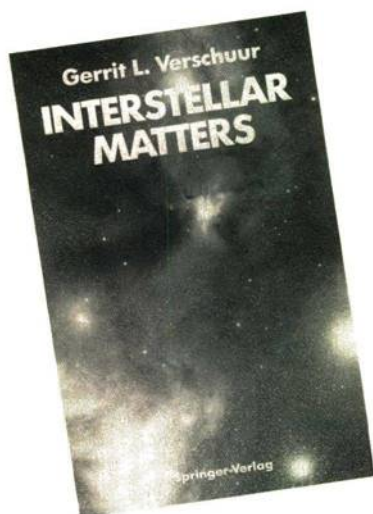
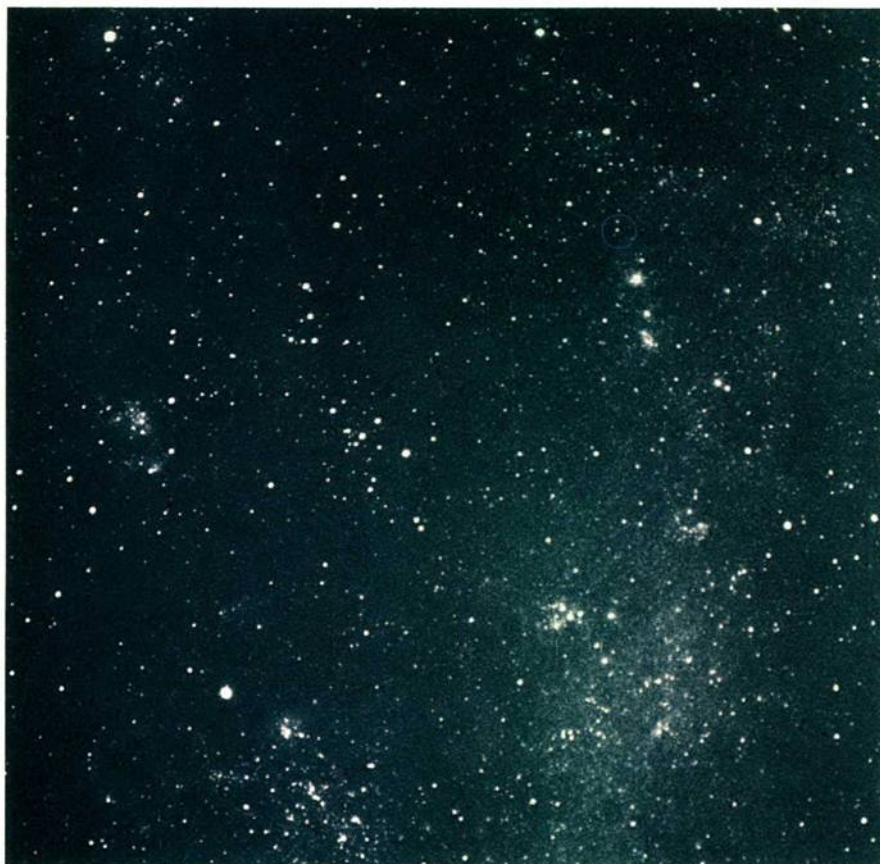
THE ROTATION OF MARS is visible in this sequence made on October 8, 1988, with a 16-inch Cassegrain telescope and a CCD camera. The scope was stopped down to 5 inches in aperture. Photos by Thomas W. Fuller, Clyde Kirkpatrick, and Ramona White.

AUSTRALIAN DISCOVERS HIS THIRD LMC NOVA

Gordon Garradd of Tamworth, New South Wales, discovered his third nova in the Large Magellanic Cloud on a photograph he took October 12, 1988. Along with Rob McNaught of Siding Spring Observatory, Garradd systematically photographs the LMC hoping to find new stars in the Milky Way's largest satellite. Together Garradd and McNaught have found five LMC novae during the past two years.

"On my photograph of October 12.5 UT I found a magnitude 11.3 star that wasn't on any atlas," said Garradd. "Subsequent photographs showed it brightened by a magnitude the next day and faded to 12th magnitude over the following week.

A NOVA IN THE LMC erupted on October 12, 1988. Gordon Garradd found the nova on his photograph made with a 300mm f/4.5 lens, hypered Tech Pan, and a 13-minute exposure.



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"After taking the photos," Garradd continued, "I notified McNaught, who confirmed the nova visually as soon as it was dark. We sent a discovery message to the IAU's Central Bureau for Astronomical Telegrams and later measured the nova's precise position by making a short exposure with the observatory's Uppsala Southern Schmidt Telescope."

Garradd wants other amateurs to join the search for extragalactic novae. "At the present time McNaught and I are the only ones doing a systematic patrol of the Magellanic Clouds, but our coverage is incomplete because of bad weather and other factors."

Observers who are interested in helping out — and possibly discovering a nova — should write to Garradd at P.O. Box 157, Tamworth, New South Wales, 2340, Australia.

EL NATH GRAZING OCCULTATION SETS RECORD

On October 12, 1987, amateur astronomers banded together for the most suc-

cessful grazing occultation ever. Four separate expeditions observed the graze of El Nath (Beta Tauri) and produced 362 timings useful to astronomers studying the Moon. (A grazing occultation occurs when a star is momentarily blocked by mountains along the Moon's limb.)

Don Stockbauer, coordinator of the Lunar Grazing Occultation Section of the International Occultation Timing Association (IOTA), reports that the El Nath graze was first observed in Tilden, Texas. (For a report on the Tilden El Nath expedition, see "Charting Mountains on the Moon" by Robert Reeves, Ron Dawes, and Rick Frankenberger, August 1988.) After the Moon's shadow passed through Tilden, it next swept across Genoa Airport, a small airfield just south of Houston.

The Genoa expedition was a joint effort of IOTA, the Houston Astronomical Society, the Johnson Space Center Astronomical Society, and the Fort Bend Astronomy Club. Stockbauer said that "three stations obtained data with video equipment, and nineteen other stations collected visual data for a total of 214

timings. As an example of the success we had, Barbara Wilson of the Houston club made twenty-four timings in just one minute and fifty seconds!

"The third expedition," Stockbauer explained, "was organized by Benny Roberts of Jackson, Mississippi. It consisted of three observing stations near McLaurin, Mississippi, which netted fourteen timings. The last observations were made by Tony Murray, who made two timings from his backyard in Georgetown, Georgia, before the shadow moved off into the Atlantic Ocean. This record of amateur cooperation made the El Nath occultation the best ever. It produced more timings than the previous record holder, the Merope occultation of February 10, 1973."

Stockbauer invites observers to join him in observing the grazing occultation of Regulus on November 30, 1988. The graze will be visible near Houston, and Stockbauer is planning an expedition to Wharton, Texas. Interested observers can contact Stockbauer at 2846 Mayflower Landing, Webster, Texas 77598; (713) 338-1980.

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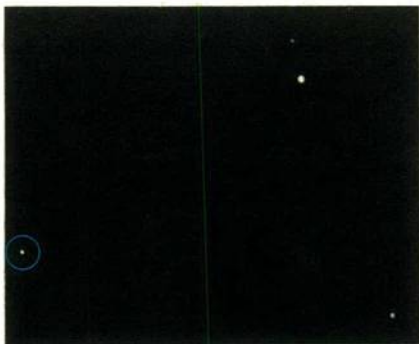


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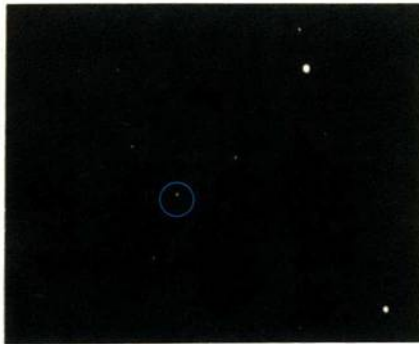
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CERES PASSES BRIGHT STARS IN AQUARIUS

On the nights of October 18, 19, and 20, 1988, asteroid 1 Ceres slowly passed between two bright stars in Aquarius. The 5th-magnitude stars 103 and 104 Aquarii are separated by 10' and oriented north-south. The 7th-magnitude asteroid moved slightly north but mostly west, so it passed through the stars at right angles to the line separating them.

Two graduate students at the University of Florida at Gainesville photographed the event. Daniel D. Durda, director of the university's student observatory, and Dirk Terrell, recorded the passage with an 8-inch f/13 Clark refractor and exposed

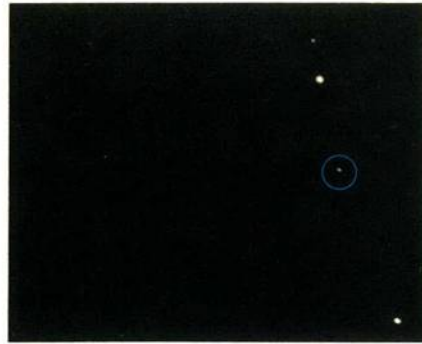


ASTEROID CERES PASSES STARS in Aquarius in this sequence made at 1:45 UT on October 18, 19, and 20, 1988, by Daniel D. Durda and Dirk Terrell with an 8-inch Clark refractor.

for 30 seconds. "We would have made longer exposures," said Durda, "but the telescope is eighty-two years old and has a very cranky drive mechanism!"

UNUSUAL SIGHTING ON LUNAR LIMB

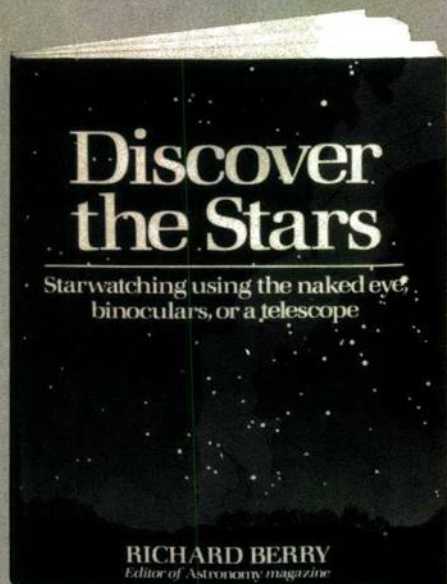
On the evening of October 16, 1988, Carl Buzzard of the Chicago Astronomical Society made a most unusual observation on the Moon. "I saw a fast-moving object appear to impact the surface of the Moon," said Buzzard.



"I was on the roof of my brother's apartment building in Collingswood, New Jersey," he continued, "observing with my 10-inch f/9 reflector. After showing my nephews Saturn, I turned the telescope on the Moon. I was bringing the Moon into view, scanning the limb in the area of the crater Langrenus, when I saw what looked like a fast-moving meteor enter the field and strike the lunar surface, creating a small plume." Buzzard's observation has not been confirmed.

Buzzard estimated that the event he saw occurred at approximately lunar longitude 75° east, latitude 12° south, which

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places it near the craters Kapteyn and Ansgarius. Reports that could confirm this disturbance on the Moon should be sent to Buzzard at 3081 Lynnwood Court, Streamwood, IL 60107; telephone (312) 837-1201.

COMET TEMPEL 2 ENCOUNTERS GLOBULAR CLUSTER

Periodic comet Tempel 2, one of the brightest celestial visitors of 1988, paired up with the globular cluster M54 in Sagittarius last October.

Arizona astrophotographer Chris Schur recorded the encounter with an 8-inch f/1.5 Schmidt camera. He described the pair's appearance in his 16-inch reflector. "Visually Tempel 2 and M54 made an impressive sight. In the same low-power field I saw an unresolved globular cluster with a blazing center and a softer, dimmer patch of light that appeared uniformly illuminated across its surface. Together the objects showed me that clusters and comets appear distinctly different." — David J. Eicher □



COMET TEMPEL 2 AND CLUSTER M54 were photographed together on October 8, 1988, by Chris Schur. M54 is the bright fuzzy object; the comet is fainter and lies above the cluster. Schur used an 8-inch f/1.5 Schmidt camera and hypered Tech Pan film for the photo.

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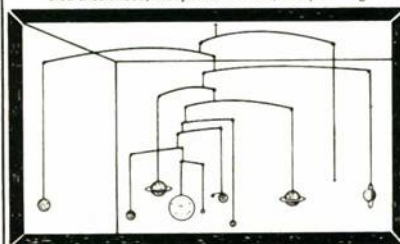
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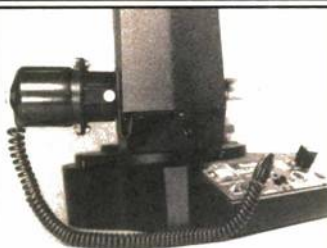
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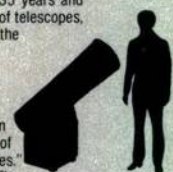
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On July 20, 1969, two American astronauts landed on the Moon. As I watched the momentous event on television, I was moved to look at the Moon, not just an image of the Moon. I had to see if the Moon looked any different.

I set up my 60mm refractor in the front yard. The Moon, magnified thirty-seven times, burst into view in the eyepiece. I focused my telescope on Mare Tranquillitatis, the astronauts' landing site.

I couldn't see the astronauts and hadn't expected to, but I was surprised to find that the Moon did look different. Though I had surveyed the stark lunar features a hundred times and could recognize and name dozens of craters, mountains, and basins by name, the Moon now looked more familiar, more neighborly. It looked less like the Moon and more like American soil.

Naturally the lunar landing was hailed as one of the great adventures of discovery. It was an astounding enterprise, but one should keep things in perspective. Consider the voyage of Ferdinand Magellan, the first circumnavigation of the Earth, begun in 1519. This mission was an epoch-making success, though the discoveries were basic: the theretofore unimagined extent of the Pacific Ocean, the realization that the Earth's surface consisted of more water than land (it had long been believed that Earth was six-sevenths land), and, best of all, that by means of the oceans you could go anywhere on the planet.

Today with our full-color photographs of Earth from space it's difficult to appreciate the magnitude and impact of Magellan's discoveries. Whole systems of geography and even a few cosmological and theological dogmas were proved wrong. After Magellan, entire world views fell by the wayside.

This experience of discovery — of seeing the world from a new perspective — is not something limited to a fortunate few. We can each make our own personal journeys of discovery. I made mine one cold, clear night in February as I tried to understand the distance to the stars.

I'd long been familiar with the term light-year, but I was in a restless, questioning mood that evening, and I tried to comprehend what that unit of distance really meant. I stood gazing at the star Rigel, the bright bluish star in Orion's leg, transfixed by the notion that the star is 750 light-years away.

I mentally projected myself toward the star. What if my backyard were as big as



Earth, and Earth were as big as the Sun, and the Sun as big as the solar system, and the solar system as wide as the distance to the nearest star? I began to lose track of time.

Suddenly my concentration broke. Stunned, I realized I couldn't comprehend a light-year. The world blew up in my face. The normal, mind-assuaging lines of perspective went awry, and I was temporarily overwhelmed by the immensity of the universe. With a flash of insight I realized that the stars were not up: they were all around me. I wasn't looking up at the sky but out at the sky from the surface of a tiny ball. For the first time I was aware of being on a planet, a literal spaceship, and the stars were outside it, all around. I was an astronaut.

Although I couldn't actually see it, I became aware of Earth gently curving away toward South America. I turned and sensed Earth sloping toward the North Pole. The sky resolved itself into a deep, three-dimensional galaxy-shape. Stars surrounded me on all sides.

I stared at Polaris, the target of Earth's axis, and for a precipitous few moments I felt as if I were falling toward the north star. I gasped and quickly shifted my attention to my familiar lopsided garage. Gravitational pull returned in a rush and I resumed that familiar rooted sensation — but the stars would never be the same.

Magellan's circumnavigation and Apollo 11's landing made history. But to me they are not more significant than what I discovered in my own backyard.

— Peter M. Leschak

SHARING ASTRONOMY ACROSS THE ATLANTIC

Letters from Michael Ottink, my astronomical pen pal in Holland, brought news of his astronomy club, the European Space Agency, and the objects he observed. As a result of a classified ad I had placed in *ASTRONOMY*, Michael and I had been corresponding for two years. I had often wished I could meet my pen pal, and in 1985 I finally did.

Mike wrote to tell me he would be visiting Florida with his Dutch astronomy club to see Wubbo Ockels, a Dutch *Spacelab* payload specialist, liftoff in the space shuttle. I was overjoyed with the news. Mike said he would also have time to visit me at my home in Alexandria, Virginia.

At the beginning of November Mike sent me a postcard from Florida that said he would be arriving at the Alexandria bus terminal on Friday, November 8, or Saturday the 9th. By 8 p.m. on Friday I figured his bus would arrive on Saturday. But as soon as I gave up hope, I heard a light tapping on the front door. Outside in the dark stood a tall, slender figure with a bag in each hand. "Is that you, Mike?" I said. He smiled and nodded.

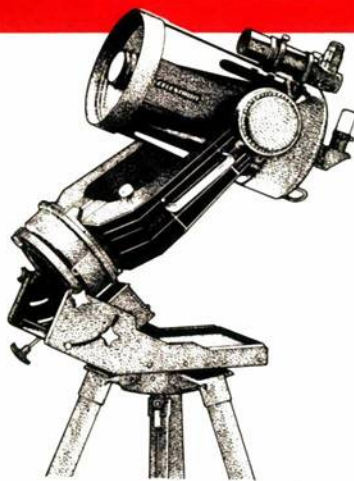
After introducing Mike to my parents, he went through his bags and pulled out two strange-looking rocks. Mike told me they were meteorites he had purchased in Florida. My eyes lit up as Mike gave me one as a gift.

Time flew by that weekend. We were always busy doing something, but the little time we had at home we spent discussing how we lived in our different countries, our ideas on astronomy, and the space programs of our respective nations.

For two nights Mike and I tried to find Halley's Comet, but we were unsuccessful, much to our dismay. It was something we had wanted to see together. We did see many other celestial sights in that memorable autumn sky. For once I was stargazing with somebody who knew about everything from eyepieces to M42.

Monday came and Mike had to leave for Florida to meet his group and fly back to the Netherlands. I felt as if an old friend were moving away.

About a week after Mike left, I ventured outside into the crisp November night, this time without my astronomical friend. I pointed my telescope at where I thought Halley was. Lo and behold, there it was in my telescope's field of view, that special sight that had evaded Mike and me. I smiled and felt that, somehow, my astronomical friend across the miles was looking too. — David Abbou



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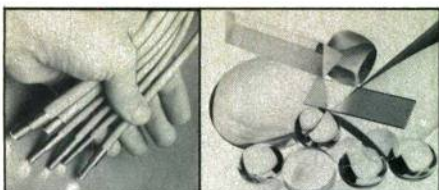
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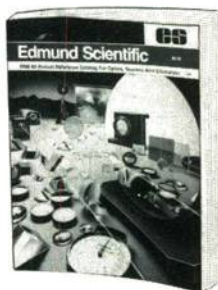
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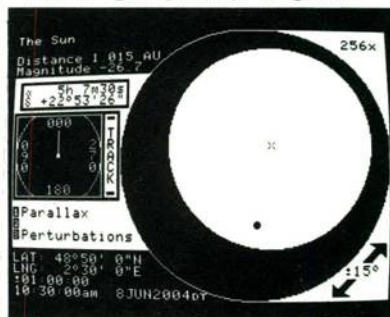


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Astronomy Books

COSMOLOGY'S ERA OF DISCOVERY

Gravity's Lens: Views of the New Cosmology by Nathan Cohen, (John Wiley and Sons, 1988), ISBN 0-471-63282-1, hardcover, 237 pages, \$19.95.

When you look at the string of astronomical breakthroughs in the last seventy-five years, it becomes clear that astronomy is building toward a crescendo of discovery. The expansion of the universe, the cosmic background radiation, pulsars, quasars, and gravity lenses have painted a vast, violent universe that both challenges and bedevils astronomers.

Certainly there are some empty swaths in this emerging picture. For example, how did galaxies form? The essentially unvarying temperature of the cosmic background radiation — the afterglow of the Big Bang — implies that the universe should be as smooth and uniform as creamy tomato soup. Yet there are significant irregularities in this otherwise uniform universe in the form of billions of galaxies. What caused these irregularities and how did galaxies form from them?

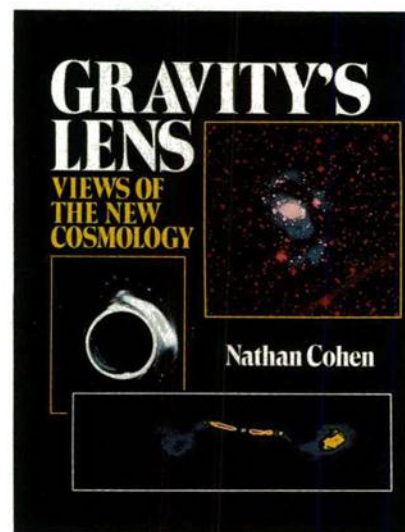
The jury, as Nathan Cohen notes in his book *Gravity's Lens*, is still out on this one — way out. Even the most favored galaxy formation theory today is on shaky legs. One wonders if it is wise to believe any of these theories too much, no matter how neatly they appear to bridge the gap between speculation and fact. After all, it's a very long span and the gorge is bottomless.

Plain and simple, *Gravity's Lens* is a compelling account of the emerging viewpoints in modern cosmology. It presents the most recent discoveries and theories and shows how they all connect to form our current picture of the universe. Complex topics like dark matter, cosmic strings, and gravitational lenses are explained in a lively, unassuming style that's easy on the jargon. The book's graphic appearance is also appealing. It contains numerous diagrams and black-and-white photographs as well as two sections of color plates illustrating such phenomena as active and colliding galaxies, radio jets, and computer-generated images of gravity lens models.

Part one, entitled "Previews," lays the groundwork for the concepts of the new cosmology, which is introduced in part two. Cohen walks us through the development of observational astronomy from Galileo to the discovery that galaxies are star systems apart from our own — two milestones that swept away many a cozy theory of the universe.

Avoiding a detailed rehash, Cohen moves efficiently down the timeline, hitting the historical high points of Doppler shifts and distance measurements, and the curious discovery that the spectra of most galaxies are redshifted. By the end of chapter one we encounter the foundation upon which much of modern cosmology is built: the expanding universe.

The discovery of cosmic expansion had



a profound effect on our perception of the universe. Today such a concept seems a foregone conclusion. To the person on the street, an expanding universe is no more startling than an expanding economy. But sixty-five years ago the notion that galaxies were rushing away from one another was a revelation as disturbing as Galileo's telescopic views of an imperfect universe were to seventeenth-century scientists and theologians.

Subsequent chapters on the Big Bang, the cosmic background radiation, and quasars — all leading to a culminating chapter on cosmological models and questions — complete the picture of the universe we have today: a universe more or less strung together with systematic observations. Although observations often lead to significant discoveries, the discoveries tend to pose more difficult riddles that leave us in the lurch. What is the nature of quasars? Is there hidden mass in galaxies? What is the expansion rate of the universe and will the universe expand forever or collapse in the future?

These are some of the major questions astronomers are asking today. To find the answers requires more information than

can be obtained with optical observation alone. Thus, in part two, Cohen presents the universe as revealed by sophisticated instruments and computer imagery, and delves into the latest theories spawned by these observations. By exploring the universe at wavelengths longer and shorter than visible light, astronomers are learning a great deal about "hidden" astrophysical processes. It is in the realms outside the optical window that astronomers are gathering the most information about the energy source of quasars, the environment of radio galaxies, and the ubiquitous cosmic background radiation.

One of the most valuable attributes of Cohen's book is its fair-minded assessment of such established theories as the Big Bang and the grand unified field theories. If he is biased toward or against any particular model or theory, his biases are not apparent. He injects a balanced perspective into the text by constantly placing theories into context with observational data.

The third and final part of the book touches on a number of cosmological issues and discoveries that have arisen in the last ten years: cosmic inflation, dark matter, primeval galaxies, cosmic strings, gravity lenses, and supernova 1987A. These are each described in brief, easily read sections that provide "a flavor of the new cosmology's continued progress." Cohen concludes that we are on the brink of a new era of exploration that will be "ushered in by the findings of the new cosmology."

In one sense, *Gravity's Lens* is a book concerning what we know or have recently learned about the universe. In a larger sense, however, it is a book about the potential of our understanding. Cohen describes cosmology as an "evolving science and an incomplete one." As enigmatic as the universe is, the recent flurry of astronomical discoveries shows us that at least some of the cosmos is within reach. How much more of the universe is knowable depends on the limits of our intellect. — Jeff Kanipe

A WINDOW ON THE ZODIAC

Astrowatch by Ben Mayer, (Perigee Books, 1988), ISBN 0-399-51431-7, paperback, 143 pages, \$10.95.

Ben Mayer's *Astrowatch* is a fun project book specifically designed to help the beginner learn the zodiacal constellations — the twelve star-figures that straddle the ecliptic. It is in these constellations that the apparent paths of the Sun, Moon, and planets are tracked throughout the year. Complete instructions are given so you

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can construct transparent "stellaphanes," simple tools to identify these constellations.

A stellaphane is made from a wire coathanger shaped to form a window frame. On a sheet of plastic kitchen wrap, you trace a constellation as given in the book and then cover the coathanger with your tracing. Two views for each constellation, one each for Northern and Southern Hemisphere views, are included. By holding the stellaphane about fifteen inches from your face, you can align the drawn stars with the real ones. Marked on the star maps is a camera target symbol: you aim a 35mm camera equipped with a 50mm lens at this target so you can take a complete photo of the constellation.

Each constellation is given its own five-page project, which includes historical information, illustrations showing how to locate the constellation, a list of that constellation's culmination dates (meridian crossing), and a listing of the brightest stars in the constellation. This brightest-star list gives the star's Greek letter, name, distance in light-years, and magnitude. In large letters across the top of the third page are the constellation's formal name, English translation, possessive form, and abbreviation. Finding constellations is easy because the abbreviations of constellations are placed at the corner of each page — one of the many little things the author did to make this book so handy.

The last two project pages are the ones you use to trace your stellaphanes. I made some stellaphane tracings by using a copy machine and the transparent plastic used with overhead projectors. Mr. Mayer's concept does indeed work.

A two-page table gives you the culmination dates for each hour, from 19 to 15 UT, to view each zodiacal constellation. A handy feature of the table is that the full name of the constellation is given on the left side and its standard abbreviation is given on the right.

Ever wonder when and in what constellations Mars, Jupiter, and Saturn will be visible from 1988 through 2000? *Astro-watch* includes a table compiled by Jenny Pon of the Abrams Planetarium with this information.

Also covered are such topics as meteors, adapting your eyes to the dark, viewing and photographing the Moon, galaxies, using binoculars, and building a motorized camera mount for your regular camera tripod.

This book is a must for the young as well as the adult beginner. The projects make learning about the zodiacal constellations a fun, hands-on experience. I hope

Mr. Mayer is making a book like *Astro-watch* to cover the other seventy-six constellations. — Robert A. Garfinkle

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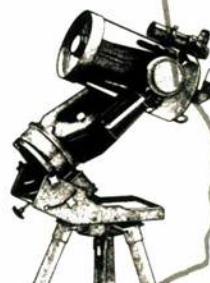
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25x100 Wide-Field Binoculars, (T.R. Inc., P.O. Box 65, Mooers, NY 12958), \$1,360.

In addition to portability, binoculars have two particular benefits for astronomical users. First, binoculars involve both eyes in observing. Because the brain is accustomed to receiving optical information from two sources simultaneously, this increases visual sensitivity. Second, because binocular magnifications are modest with respect to their light-gathering power, they are ideal for viewing extended Milky Way fields and large, low surface brightness celestial objects.

Most binoculars used in astronomy have objective lenses 50mm in diameter; those with larger objectives are usually called "giant binoculars." By this standard, T.R.I.'s 25x100s might be called "supergiant" binoculars. They are big (14 inches long) and heavy (7 pounds). Anyone can hold 10x50 binoculars almost perfectly steady if his or her arms or elbows are braced against something. But these 25x100s are usable only on a tripod — and a heavy one at that.

However, once you've gotten them on a good mount, these 25x100 binoculars are a delight to observe with. Indeed, I found quite a few celestial objects and Milky Way fields more beautiful in these glasses than in even the finest observatory photographs.

The best way to give you some idea of the capability of the 25x100s is to describe what different kinds of celestial objects looked like in the field tests I conducted over several months.

Planetary nebulae are generally too small to show a disk even at 25x, though I did see the squarish figure of the Dumbbell (M27) and glimpsed the central hole in the Helix (NGC 7293). Double stars likewise require more magnification than binoculars provide. But certain wide pairs were beautiful: Albireo and 61 Cygni, to name two. (In general, I found the 25x100s could split doubles 10" or more apart, providing the stars were roughly equal in brightness.)

On to galaxies. The central hub of M33 in Triangulum appears as a dim little disk embedded in the pale, oval haze of the galaxy; 10' northeast of it is a fuzzy spot, NGC 604, which is a huge emission nebula in one of the spiral arms. M31's inner dust lane can be seen clearly with averted vision. I also saw NGC 6822 in Sagittarius, a dwarf irregular galaxy in the Local Group that is impossible to see in ordinary binoculars.

Star clusters? I spotted fourteen globulars in Sagittarius and thirteen in Ophiuchus. M4 in Scorpius and M22 in Sagittarius were resolved into tiny star-specks glittering on the background haze. The Double Cluster in Perseus fit well into the 2.5° field; the Pleiades were prettier than any photo I've seen. Among the diffuse nebulae you can see the dust lane in M8 and a bright filamentary arc on the north-east rim of the California Nebula. Both arcs of the Veil in Cygnus were easy.

The only problem I had with the optical performance of the binoculars is that star colors did not seem as intense as in other binoculars I have used: strong orange was muted to ruddy orange and ice-blue to blue-white. There was also a noticeable amount of chromatic aberration that surrounded bright objects with distinct haloes. (When you look at faint objects, the haloes are too dim to see, however.)

I had one mechanical problem with the 25x100s: one of the elements of the left-hand objective lens seemed to be loose. Strangely, this didn't affect the optical quality of the image, but it probably caused the frequent refocusing I found necessary. My guess is that with normal handling the loose element sometimes slipped out of position.

Maybe I'm not hard to please, but I found the performance of these binoculars worth the four-digit price tag — even with the additional cost of a heavy tripod. The instrument comes with a tripod mounting plate and a padded, hard-sided carrying case.

Who would buy this instrument? That depends on what you want from astronomy. I wouldn't recommend it for beginners: they should start with 10x50s or 7x50s. And if you feel astrophotography or variable star observing is where you're headed — or if you simply want a "light bucket" for finding as many galaxies, planetaries, and clusters as you can — you'd be better off investing in a large-aperture Dobsonian. But if such wide-field activities as nova- or comet-searching appeal to you, then these binoculars could be very useful. After all, Comet Machholz (1988j) was discovered with 27x120 binoculars.

I guess it comes down to taste. If you're an astronomical hedonist like me and revel in stunning Milky Way starfields, ghostly nebulae and galaxies hovering in the night, and rich, glittering galactic star clusters, then these 25x100 binoculars are a good alternative to a comparably

priced Schmidt-Cassegrain telescope and will give you many nights of enjoyment.
— Craig Crossen

OTHERWORLDLY MUSIC

Galaxies by Kevin Braheny, (Hearts of Space, 1988), chrome cassette tape (duration 57:35), \$9.98 (also available as a CD, \$16.98).

Gustav Holst's orchestral suite *The Planets* used to be the one inescapable piece of planetarium background music. While that old warhorse of the classical repertoire remains popular, a new contender has stepped to the fore. Usually known as New Age music — and instantly recognizable to many who may have never heard the name — the new music features slow, sweeping chord progressions and soft glissandos that evoke an otherworldly atmosphere.

Kevin Braheny's *Galaxies* lies firmly in this new tradition. It was composed as the soundtrack to a planetarium show that was written and directed by Timothy Ferris and based on Ferris' book of the same name. *Galaxies* has sixteen cuts that range in length from 42 seconds to 6:26, and all of them are performed on synthesizers.

If you tune into your local National Public Radio station, you will probably find a show called "Hearts of Space." *Galaxies* is very similar to that program, and the dreamy effect that "Hearts of Space" provides is a good sample of what this music is all about.

Reactions to New Age music vary greatly. For my taste, Braheny relies too much on the swoosh-and-tinkle sounds, but his work is never unpleasant to listen to and it probably succeeds very well as background for planetarium shows. It might also go well with observing if you like a soundtrack to accompany your activities.

I'm not sure if this is a recommendation or not, but I frequently hear this kind of music floating out of ASTRONOMY editorial offices, especially as we get close to deadline! — Robert Burnham

OBSERVING AIDS

Tapes of the Night Sky by the Astronomical Society of the Pacific, two cassette tapes plus booklet, \$16.95.

The goal of these new *Tapes of the Night Sky*, which are an update of an earlier version, is to acquaint any beginning skywatcher with the basic constellations visible from the Northern Hemisphere in each season of the year. It requires only a cassette player you can take outside and



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a clear, moonless night.

The commentary on the sky for each season takes up one side of each tape and the sixty-page booklet is a reprint of the full text. It also provides four small, removable seasonal sky charts.

Nightsky, (Southwest Astronomy, 4242 Roma N.E., Albuquerque, NM 87108), \$59.95.

Nightsky is a program for PCs and compatibles that generates star maps (two thousand stars, magnitude 5.0 and brighter) on the screen or on a printer. It also produces planetary data tables (positions, rise/set times, Galilean moon diagrams). In its clock mode, *Nightsky* converts local, sidereal, and universal time, gives Julian and Gregorian dates, and calculates the Moon's position, phase, and rise/set times. The program also lets you create a database of objects and information about them.

UPDATE

The *Observer's Notebook* listed in November's Astronomy Products has been changed slightly: the New General Catalogue listing now goes to magnitude 14.9 and all spurious objects have been removed. The notebook is no longer published by the Los Angeles Astronomical Society; instead, please make all checks (for \$20 plus \$2 shipping and handling) payable to Randy Kolar, 7 Vercelli, Irvine, CA 92720. □



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Meetings and Events

January 8-12

173rd Meeting of the American Astronomical Society, Boston, Massachusetts. Professional meeting hosted by the Massachusetts Institute of Technology. Contact: American Astronomical Society, 2000 Florida Avenue, N.W., Suite 300, Washington, DC 20009.

January 14

Astronomy Day, Columbus, Georgia. Sponsored by Patterson Planetarium. Contact: Carole Rutland, Director, Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, GA 31907. Phone: (404) 568-1730.

February 2-5

5th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

February 25

Astrophoto VIII, California State University at Fullerton. Seminar and photo exhibit co-sponsored by the Orange County Astronomers and the Ventura County Astronomical Society. Contact: John Sanford, 2215 Martha Avenue, Orange, CA 92667. Phone: (714) 639-8446.

March 4

Astronomy Day, Museum of History and Science, Louisville, Kentucky. Sponsored by the Louisville Astronomical Society. Contact: Ingrid Siegert-Tange, 1825 Windsor Place, Louisville, KY 40204. Phone: (502) 459-6689.

March 9-12

Third New Zealand Photo-Electric Conference, Blenheim, New Zealand. Contact: Stan Walker, Auckland Observatory, P.O. Box 37 735, Auckland, New Zealand. Phone: 64 (9) 548-736.

March 18

New England Astro-Fest #2, Farmington, Connecticut. Commercial astronomy equipment exhibition, sponsored by New England Astro-Optics, Inc. Contact: New England Astro-Optics, Inc., Attention: Astro-Fest #2, P.O. Box 834, Simsbury, CT 06070.

April 28-30

3rd Annual Southern Star Conference, Wildacres retreat in the Blue Ridge Mountains of North Carolina. Hosted by the Charlotte Amateur Astronomers. Contact: Heather Fisk, P.O. Box 220234, Charlotte, NC 28222. Phone: (704) 332-4670.

May 13

16th Annual Astronomy Day. Contact: Gary E. Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson Avenue SE, Grand Rapids, MI 49503. Phone: (616) 456-3985.

May 19-21

Royal Astronomical Society of New Zealand Conference, Invercargill, New Zealand. Sponsored by the Southland Astronomical Society, Inc. Contact: Darryl Jones, Southland Museum and Art Gallery, P.O. Box 1012, Invercargill, New Zealand.

May 29-June 4

Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: T.S.P. Registrar, Bobby Braley, Department "A," P.O. Box 386, Wylie, TX 75098.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. □

READER EXCHANGE

ANNOUNCEMENT — The Skokie Valley Astronomers meet on the second Friday of each month at 8 p.m. at the Ryerson Nature Center, 21950 Riverwoods Road, Deerfield, IL. Free admission. Member presentations are followed by star parties. All ages welcome. Contact Dale Dellutri, 2411 Cowper, Evanston, IL 60201.

FOR SALE — Dynamax 8 f/10 Schmidt-Cassegrain telescope, 8x50 finder, fork mounting, electric clock drive, setting circles, 30mm eyepiece, and field tripod. Mint condition, hardly used. \$1,000 including shipping. Contact Joanie Rhoda, R.R. #3, Box 9470, Union, ME 04862. Phone (207) 845-2437.

WANTED — Soil samples from around the world for Earth science class. Contact Dave Pinch, 1490 Lark Avenue, Maplewood, MN 55019.

FOR SALE — Celestron SPC102 102mm refractor, Super Polaris mount, finder scope, tripod, right ascension and declination drives, dual-axis drive corrector, slow-motion controls, setting circles, and more. Pristine condition. \$850 including shipping. Contact Henry Bertrand, 5711 MacArthur Boulevard, New Orleans, LA 70131. Phone (504) 394-6377.

WANTED — Meade 8" f/4 Schmidt-Newtonian MTS-SN8. Contact Kenneth Ung, 163B Starr Road, Cheswick, PA 15024. Phone (412) 265-5177.

WANTED — Correspondence with anyone interested in geology, astrogeology, celestial mechanics, computational spherical astronomy, and making predictions with a calculator. Contact Lee Martin, R.R. #1, Box 55, Greenwich, OH 44837.

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Triton (page 20)

"Aiming at Neptune" by Charles Kohlhasse, *ASTRONOMY*, November 1987. A behind-the-scenes glimpse at the techniques used to target *Voyager 2*.

Uranus and Neptune, (NASA Conference Publication 2330). A compendium of papers presented in 1984 that still pretty closely represents current thinking.

"Voyager's First Glimpse of Neptune" by Richard Berry, *ASTRONOMY*, October 1988. Triton is an orangish blip in the first *Voyager* photo of Neptune.

Barnard's 'Dark' Dilemma (page 30)

Eye on the Sky: Lick Observatory's First Century by Donald E. Osterbrock, John R. Gustafson, and W. J. Shiloh Unruh, (University of California Press, 1988). A history of Lick. Includes vignettes about Barnard.

Interstellar Matters by Gerrit L. Verschuur, (Springer-Verlag, 1988). The discovery and implications of interstellar matter. Opens with a section on Barnard.

Supernova Aftermath (page 40)

"Insight into Star Death" by Richard L. Talcott, *ASTRONOMY*, February 1988. A look at why supernovae occur and what happens after a star explodes, with an

emphasis on supernova 1987A.

The Supernova Story by Laurence A. Marschall, (Plenum Press, 1988). A non-technical account of supernovae and their aftermath.

Safe Solar Viewing (page 66)

How to Use an Astronomical Telescope by James Muir, (Linden Press/Simon and Schuster, 1985). An easy-to-read, nuts-and-bolts approach to solar observing. Contains diagrams for solar projection and making stop-down masks.

Eclipse Prospects (page 71)

Solar Eclipses 1991-2000 by Alan D. Fiala, James A. DeYoung, and Marie R. Lukac, (U.S. Naval Observatory, Washington DC 20390, Circular No. 170). A resource that contains maps and tables for each solar eclipse of the decade.

A Picture-Perfect Eclipse (page 78)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). Includes techniques for photographing lunar eclipses.

The Astronomical Almanac for the Year 1989, (U.S. Government Printing Office, 1988). Includes the fundamental data for each of the four eclipses in 1989.

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2045/2045 LX3

2045 LX3	Call
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6.4, 9, 12, 14, 15,	4.7mm	13.8mm
20.25	6.7mm	14.75mm
32, 40mm	8.8mm (1 1/4")	18mm
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Barlow 2X	14mm (1 1/2")	32mm (2")
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ASTRONOMY Advertisers

February 1989

A.M. Plastics	97
Academic Press, Inc.	27
Ad-Libs Astronomics	51
Adorama Camera	108-109
Andromeda Software, Inc.	102
Astro Cards	97
Astro Flea	97
Astro-Tech	105
ASTRONOMY Products	9,39,44-45,52,54, 55,83,86,87,94,95

Bill Weaver Sporting Goods 103

Caledonian Graphics	106
California Telescope Co.	12-13
Celestron International	15,112
Century Telescope Center	54
Chaucer Industries, Inc.	106
Cosmic Connections, Inc.	97
Coulter Optical Co.	98

Edmund Scientific Co. 100

Faraday & Wheatstone	86
Focus Camera, Inc.	77

History Book Club 11

Jim's Mobile Industries 97

Lightspeed Software	100
Lumicon	28-29

Meade Instruments Corp.	2-3,17
Meteorites	106
Miko	52

National Camera Exchange	19,99
New England Astro-Optics, Inc.	106
Northern Sky Telescopes	70

Optica b/c Co.	102
Orbic Systems	97
Orion Telescope Center	69

Parks Optical	53
Pauli's Wholesale Optics	97,102

Quasar Optics, Inc. 106

Robert Waxman, Inc. 103

Scope City	83
Scope City (Canada)	86
Shutan Camera & Video	101
Springer-Verlag	93

Tele Vue Optics, Inc.	7,111
Tuthill, Roger W., Inc.	43,96

University of Texas-Austin 104

Wellock Instructional Needs	102
Wholesale Optics of PA	83

Z2 Computer Solutions	86
Zephyr Services	104

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COMING IN THE MARCH 1989 ISSUE OF ASTRONOMY

Our Sun through Many Eyes For the first time astronomers have observed the Sun at all wavelengths of the spectrum.

New Telescopes for New Stars The new branch of submillimeter astronomy gives astronomers a way to watch the birth of stars.

Springtime Galactic Showpieces Visible even in binoculars, bright spiral galaxies herald the arrival of spring.

AVAILABLE ON YOUR NEWSSTAND FEBRUARY 14

READER EXCHANGE

ANNOUNCEMENT — The Astronomical Society of American Samoa holds its weekly star parties Friday nights from 7:30-9 p.m. in the Leone High School field. Telescopes include a Coulter 17.5", Coulter 8", Meade 10" SCT, and Criterion 6". Contact ASAS, P.O. Box 3076, Pago Pago, American Samoa 96799.

ANNOUNCEMENT — Satellite/Space Information News Net and Seismic Precursor Net stimulate southern California ham-radio operators into scientific discussions and calculations. Written observations invited. Send a #10 SASE and \$2 for summary. Contact SPN, Box 306, Lakewood, CA 90714.

FOR SALE OR TRADE — Space program materials including books, photos, press kits, crew activity plans, models, and audio and video tapes of manned and planetary exploration. Miscellaneous issues of *ASTRONOMY* and *Sky & Telescope* from 1973-1981. For more information send a large SASE (two stamps). Contact Tim Linder, 127 Edgewood Avenue, Landrum, SC 29356.

FOR SALE — Meade 2080 LX5, MCOG, declination motor, dew shield, Nikon camera mount, 8" glass solar filter, and 7.4mm, 26mm, and 40mm Plossls. Six months old. Mint Condition. \$1,500 or offer. Contact Nick Graetz, 5320 Foxlair Road, Chapel Hill, NC 27516. Phone (919) 929-7831.

FOR SALE — Meade 6" f/8 reflector, finder scope, electric drive, 6mm and 40mm Meade eyepieces, equatorial mount, and setting circles. Hardly used. Will deliver within 150 miles of Chicago. \$600 or best offer. Contact David Drizner, 2462-A West Birchwood Avenue, Chicago, IL 60645. Phone (312) 262-5168.

FOR SALE — Meade 6" Newtonian telescope with three eyepieces and 120-volt clock drive. Must sell, will accept best offer. Phone Gary at (516) 549-8206.

FOR SALE — 8" Dynamax with massive C-14 wedge and tripod, seven eyepieces, Criterion drive corrector, off-axis guider, and counterweight. Best offer. Contact Dennis Spitz, 253 Fletcher Avenue, Valley Stream, NY 11580. Phone (516) 825-6232 (evenings).

FOR SALE — Bausch & Lomb Banner 1000 3.1" f/12 refractor with equatorial mount, three 1-1/4" eyepieces, star diagonal, illuminated polar-axis finder, 6x24 finder scope, dust cap, and sturdy wooden tripod with accessory tray. New in April 1988. \$430. Contact Tom Drum, 460 Tompkins Street, Elmira, NY 14901. Phone (607) 733-2616.

FOR SALE — 4" f/15 brass Nitron refractor, 8x50 brass finder, Super Polaris mount with drive corrector, portable power supply, and hand-rubbed mahogany tripod. Beautiful and functional. \$1,050. Phone (415) 692-5337.

FOR SALE — Meade 2080 LX5 telescope with electronic focus, declination motor, photo accessories, and dew zapper. Call for list of extras. Paid \$2,300, asking \$1,450. Phone (203) 456-2517 (evenings).

FOR SALE — Edmund Astroscan telescope. Upgraded with a 13mm Tele Vue Plossl in mint condition. Rarely used. Excellent condition. \$175 plus shipping. Contact Peter Turkowski, P.O. Box 144, Central Square, NY 13036.

FOR SALE — Meade 9.7mm and 15mm Super Plossls, LX/5 declination motor #39. \$50 each. Thousand Oaks 8" solar filter. \$40. Novak 10" Newtonian parts: spider, holders, mount focuser. All new. Contact Wayne Farrant, 5733 180th Way S.W., Rochester, WA 98579. Phone (206) 273-7338.

FOR SALE OR TRADE — U.S. Navy submarine binoculars. 40 pounds. Will sell or trade for 20x80 deluxe binoculars. Phone Scott McCann at (301) 757-1991.

FOR SALE — Observatory. Three meters, thirty-three feet tall on large suburban lot with an energy-efficient, maintenance-free, three-bedroom brick ranch home with family room, recreation room, and two-car attached garage. Located one mile from I-71 interchange. Contact Observatory Hill, 2270 Grandview Terrace, Route 10, Mansfield, OH 44903. Phone (419) 756-4733.

FOR SALE — 4mm and 12.5 mm eyepieces, 3x Barlow lens, solar filter, lunar filter, accessory tray, and tripod. Good condition. \$160. Contact Dwayne Medel, 2123 Hosmer Street, Saginaw, MI 48601. Phone (517) 752-1662.

FOR SALE — ASTRONOMY. 1974-1988. Missing a few issues. Eight storage boxes included. Excellent condition. \$250 plus shipping. Contact Margaret Kunc, 4336 Wheatland Drive, Swartz Creek, MI 48473.

FOR SALE — Meade 2120 LX5 with electric declination, electric focuser, 1-1/4" and 2" star diagonals, RFA, two Super Plossl oculars, sky glow filter, 8x50 finder, Bausch & Lomb 3000 guidescope, wedge, tripod, and more. \$1,950 or reasonable offer. Phone John Lukens at (215) 968-0193.

FOR SALE — Celestron Super Polaris C8 with Star-bright coatings and all original factory equipment. Like new. \$850. Contact Mark Hamby, 9312 Gulf Park Drive, Knoxville, TN 37923. Phone (615) 690-4246.

FOR SALE — 12-1/2" telescope on Optical Craftsman mount with Parks tube, 9-1/2" Byers gear, Astro Lab drive control, Sky micrograin focuser, and custom finder scope. \$1,800. Contact M. Stephen, P.O. Box 883, Rogue River, OR 97537. Phone (503) 582-4772.

FOR SALE — Meade 2045 with all standard accessories including 2080 tripod/wedge with 2045 adaptor, Digitrack VE300 drive corrector, University Optics off-axis guider, illuminated Orthoscopic eyepiece, T-adaptor, and tele-extender. Mint condition. All for best offer over \$800. Contact Tom McNulty, 2603 Susan Drive, East Meadow, NY 11554. Phone (516) 579-8456.

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Genesis photo courtesy Jim Riffle

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